AEROSPACE REPORT NO.
ATR-75(7365)-2

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Study of the Commonality of Space Vehicle Applications to Future National Needs (Unclassified Portion)

Prepared by
Advanced Mission Analysis Directorate
Advanced Orbital Systems Division

24 March 1975

Prepared for OFFICE OF MANNED SPACE FLIGHT
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
Washington, D. C.

Contract No. NASW 2727

Systems Engineering Operations
THE AEROSPACE CORPORATION

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FOREWORD AND ACKNOWLEDGMENT

This document represents an unclassified version of The Aerospace Corporation Report No. ATR-75(7365)-1 which comprises the midterm submission of a portion of the FY 75 Aerospace Corporation contracted studies for NASA Headquarters entitled "Study of Commonality of Space Vehicle Applications to Future National Needs." The report is based on the midterm presentation, with commentary added to the charts for continuity and explanation, and follows the presentation format. Additional information provided includes calculations, backup information, design and cost methodology, and a semi-textual derivation of the goals.

The study is being performed for NASA under the direction of Mr. I. Bekey, Study Director and Assistant Group Director of the Advanced Mission Analysis Directorate. Both Mr. I. Bekey and Dr. H. Mayer, in a collaborative team effort, personally contributed the technology forecasts as well as conceived and analyzed the innovative space system concepts found in the report. Mr. M. Wolfe contributed to the sizing and weights estimation of the unusual initiatives, as well as collecting the building block and technology requirements. Dr. Mayer prepared the bulk of the material on the future environments and goals. Mr. H. Campbell contributed the costing methodology and its exercise. Other members of The Aerospace Corporation staff also contributed to this work, and their efforts are hereby gratefully acknowledged.

CONTENTS

STUDY OF THE COMMONALITY OF SPACE VEHICLE APPLICATIONS TO FUTURE NATIONAL NEEDS

V-88971

This briefing represents the Midterm Progress Report of the study of Commonality of Space Vehicle Applications to Future National Needs, which is being studied by The Aerospace Corporation as part of its FY 75 study support to NASA Headquarters. This particular contract extends throughout fiscal 75 and has four major activities, two of them which are being reported on in this briefing.

In the first half of the program, functional requirements for space systems based on future needs and environments are to be derived, both for the military and the civil communities. Separately and in parallel, possible space initiatives based on extrapolations of technology are to be compiled without regard as to need but only with respect to feasibility, given the advanced state of technology which could exist through the year 2000.

In the second half of the program, the initiatives are to be matched against the requirements, a methodology developed as to how to match and select the initiatives to go with each of the separate plans based on the future environments, and common features of the military and civil support requirements for these programs are to be derived. The output of the program will be several sets of building block and technology activities which are likely to be needed in common by both the NASA and the DOD in their future activities in this time period.

This progress report represents roughly the halfway point in the contract and reports on the first two of the above activities, namely the functional requirements and the technological capabilities.

Several important ground rules were established at the outset of the contract in order to appropriately scope the work without unduly restricting its vitality. They are illustrated on the facing page.

OBJECTIVES

- TO IDENTIFY DEVELOPMENTS AND TECHNOLOGY LIKELY TO BE NEEDED IN COMMON BY NASA AND DOD TO SUPPORT POTENTIAL SPACE PROGRAMS THROUGH THE END OF THE CENTURY.

- IN THE COURSE OF THE ABOVE,
  - IDENTIFY LIKELY NATIONAL AND SPACE GOALS IN THE TIME PERIOD
  - COLLECT NEW SPACE INITIATIVE OPPORTUNITIES
  - DEVELOP A LONG RANGE PLANNING METHODOLOGY BASED ON APPLICABLE PORTIONS OF THE DOD PROCESS
  - STRUCTURE ALTERNATE SPACE PROGRAM PLANS
  - EMPHASIZE MILITARY PLANNING, TO COMPLEMENT IN-HOUSE NASA STUDIES

GROUND RULES

- TIME PERIOD 1980 - 2000
- NO CONSTRAINTS DUE TO CURRENT
  - / BUDGETS
  - / POLICIES
  - / TREATIES
  - / GOALS
  - / TECHNOLOGY
- NO EVALUATION OF THE RELATIVE MERITS OF SPACE VS. TERRESTRIAL APPROACHES
- EMPHASIS ON MILITARY SPACE, WITH CIVILIAN SPACE TREATED TO THE EXTENT NECESSARY FOR COMMONALITY EVALUATION; HOWEVER, ANY CIVILIAN IDEAS SHOULD BE FULLY REPORTED

E-0609

The Study Schedule as shown in this chart will result in a draft report at the end of May and a final report at the end of the contract. This is the midterm status report and is based on the midterm presentation.

The main tasks of establishing the goals, collecting the concepts, and synthesizing the initiatives will be iterated in the March time period following an exchange of data between this study and the "Outlook for Space" study.

ACTIVITY SCHEDULE - NASA TASK 2.5

SOW PARA.		TASK	S	O	N	D	J	F	M	A	M	J	J	A	MANPOWER M-M	MANPOWER %
--	1	UPDATE STUDY PLAN													0.5	1.0
--	2	ESTABLISH GOALS													3.0	6.8
2.5.1	3	COLLECT CONCEPTS													2.0	4.6
2.5.3	4	SYNTHESIZE/ANALYZE/DES-CRIBE INITIATIVES													10.0	22.7
2.5.2	5	IDENTIFY BUILDING BLOCKS													3.5	8.0
--	6	DEVELOP PLANNING METHODOL-OGY CRITERIA FOR PLAN STRUC													6.0	13.7
2.5.4	7	FORMULATE PROGRAM PLANS													10.0	22.7
2.5.5	8	REPORT PREPARATION									Draft		Final		6.0	13.7
	9	ASSESSMENT SUPPORT													3.0	6.8
		TOTAL													44.0	100.0

OUTPUTS

• BRIEFINGS	Initial	Status	Status	Final			
• REPORTS	Initial			Draft	Final		

The first section of this report presents the functions which space could perform in support of the National goals expected in the likely environment through the year 2000.

The considerations of the environment, both international and domestic, which will give rise to needs and goals for the nation in the time frame are developed in Appendix A for both military and civilian goals. The environments are only briefly summarized in this section, the goals presented, and their relation to the environments stated without development, as are the space functional requirements.

The civilian goals are discussed first, with the military goals and functions second. The civilian goals are divided into three major areas: those dealing with contributions to public service and humanistic goals; those which are materialistically oriented; and those which are intellectually oriented. They will be discussed in that order.

The future environments were developed in part based on discussion with knowledgeable people in industry, science, and government.

SPACE FUNCTIONAL REQUIREMENTS

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CIVILIAN AREA

The following four pages present an outline of some key aspects of the likely environments in the period 1980 - 2000, and some of the ten significant problem areas implied in such an environment. The forecast shown is based on the reasoning developed in Appendix A.

SOME KEY ASPECTS OF THE 1980-2000 PERIOD AS RELATED TO GOALS OF U.S. SPACE PROGRAMS

A. U.S.-WORLD INTERACTIONS

1. High and Growing U.S. Material Wealth Compared to Remainder of World

U.S. agricultural, because of combination of rich soil, favorable climate, advanced technology, and supportive government institutions, will be outstandingly productive, and provide large surpluses over domestic needs.

U.S. industry will continue exponential growth at a diminished percentage rate of increase, but with absolute increase per year larger than any other nation.

The U.S. wealth vs. the relative poverty of about two-thirds the world population and the disproportionate U.S. use of global resources will become an even more important irritant in international relations.

Impact for Space Programs

International sharing of benefits of space programs will help to ameliorate anti-U.S. feelings engendered by disproportionate U.S. wealth and consumption of resources.

2. International Economic Interdependence

U.S. economy will become more and more complicated. Both because of special materials needed by the U.S. technological society from the rest of the world, and because of the balance that foreign markets provide, the U.S. economy will become more dependent on foreign nations.

2. International Economic Interdependence (cont'd)

Impact for Space Programs

In some areas, space programs can reduce U.S. dependence on foreign nations. Again, by sharing space benefits, some interdependence in specific areas may be made more workable and even desirable as a basis for peace by shared economic interests.

3. Impact of U.S. Economy and Culture on the Internal Affairs of Foreign Governments

While individuals in foreign countries may profit by relations, be attracted to the culture, and desire closer friendship with the U.S. (and even personal participation in shared space programs), governments will feel threatened and tend to exclude the U.S. from direct effects on their citizens.

4. International Peace

This issue will remain as complicated as ever, with the U.S. in shifting, ambiguous, and unpredictable positions. It will on occasion engender, and on occasion kill, cooperative international space ventures.

B. U.S. INTERNAL RELATIONS

1. No easy consensus on domestic goals or policies.

2. Dichotomic and schizoid relationship of citizens to government.

Desired:

Less government influence on private lives, activities.

Less government coercion in jobs, economic activity. Government non-interference with business, and with economic development.

But also desired:

More government planning.

More government regulation of economic predation.

Government guaranteed economic welfare.

3. Dichotomic relation within society

Desire and respect for cultural diversity.

Demand for social conformity.

4. Condition of "The Establishment"

No clear identification of any group as really belonging to the establishment.

Establishment is a labile consortium of economic, political, intellectual, and religious interests--largely centrist orientation.

Everyone believes he is disenfranchised from the establishment--only other interests belong.

5. Personal concerns overwhelm national and international concerns. Neo-isolationism not from principle, but from lack of sustained interest.

6. Fracturing of social structures with many pressure groups within groups. Labor no longer monolithic.

7. Lack of compelling national goals, frustrated vision of national greatness, dryness of national accomplishments, denigration of national efforts--this may be the predominant feeling of the U.S. citizen. On the basis of this emotional negativism, the space program will be evaluated.

SIGNIFICANT PROBLEMS OF THE 1980-2000 PERIOD

A. <u>INTERNATIONAL</u>

1. Overpopulation and disappearance of expansion space.

2. Limitations on fundamental natural resources by current or planned methods of exploitation.

   a. Limited oil and natural gas

   b. Limited supply of specific minerals - uranium

   c. Potential exhaustion of world fisheries

3. Disaffection of non-industrialized world with affluence and high level of consumption of U.S.

4. International conflict, strife, warfare.

B. <u>NATIONAL</u>

5. Intermediary term optimization of industrial activity. Cost-benefit balance in exploitation or conservation.

6. Stable energy supplies at adiabatically adjusting prices.

7. Management of agricultural resources to provide dependable, bountiful domestic supplies and surpluses for foreign consumption at adiabatically adjusting prices.

8. Government responsibility for health and safety.

9. Frustrated vision of national greatness with morality.

10. Universal feeling of exclusion from the "Establishment."

E-0956

This page is a summary of the potential space contributions to public service and humanistic goals. The functions identified here such as monitoring of pollution, disaster warning, crop prediction, water surveillance, aid to police, control of nuclear materials, etc., are those which are difficult for the private sector to marshal and that we would expect our government to do for the people.

POTENTIAL SPACE CONTRIBUTIONS TO PUBLIC SERVICE AND HUMANISTIC GOALS

GOALS	SPACE FUNCTIONS
1. International Cooperation	• International space projects • Share benefits of U. S. space projects
2. Aid to General Safety	• Disaster warning and control • Drought prediction • Transportation safety control
3. Protection of the General Environment	• Pollution monitoring • Preservation of the ozone layer • Prediction of ionospheric disturbances • Preservation of near-space environment
4. Individual Aid and Protection	• Personal communications, emergency, and routine
5. Aids to Crime Control	• Night illumination and searchlights • Police communications and control • Traffic control
6. Internal Security	• Border surveillance against illegal entry • Control of nuclear materials
7. Improved Relation of Citizens to Government	• Better communications access between people
8. Enhancement of Satisfaction	• Develop pride in significant accomplishments

E-0957

This page is a summary of the potential space contributions to materialistic goals where the government can directly aid the economy or a segment of industry. Here the monitoring for resources, weather prediction, energy management and delivery, crop and forest surveys, disposal of nuclear wastes, finding of watersheds are typically the functions which are called for. The first goal -- that is promotion of national peace -- is treated in more depth under the military goals.

POTENTIAL SPACE CONTRIBUTIONS TO MATERIALISTIC GOALS

GOALS	SPACE FUNCTIONS
1. Promotion of International Peace	• Treaty verification • Nation-nation "hot lines"
2. Aid in U.S. Position of World Leadership	• Demonstration of innovative problem - solving; mastering of high technology; international enterprises, etc.
3. Aid in Increasing Industrial Activity	• Resource exploration • Pollution monitoring • Weather prediction and control • Transportation control • Communication facilities • Energy management and generation
4. Aid in Agricultural and Forest Management	• Weather prediction and control • Crop prediction • Forest surveys
5. Provision of New Resources	• Energy delivery
6. Acquisition of New Environment	• Large, high vacuum • Zero g
7. Use of Space to Remove Hazards from Earth	• Perform hazardous processes • Disposal of wastes

E-0958

The potential space contributions to intellectual goals are listed here with emphasis on scientific goals related to understanding of physical laws and the universe. The lists of space functional requirements summarized in the last three charts include most areas being pursued by NASA today, though some areas clearly suggest or indicate directions in which initiatives could be developed for technology or system programs.

POTENTIAL CONTRIBUTIONS TO INTELLECTUAL GOALS

GOALS	SPACE FUNCTIONS
1. Aid in Determination of Origin of Solar System	• Planetary exploration and geology • Nature of asteroids • Cometary research
2. Aid in Understanding Galactic Structure and Dynamics	• Infrared astronomy 5-500 μm • Ultraviolet astronomy
3. Aid in Understanding Cosmology	• X-ray astronomy • Observation of distant objects • Intergalactic materials study
4. Verification of Physical Laws in the Large	• General relativity experiments • Invariance of velocity of light experiments • Experiments on homogeneity and isotrophy of empty space in the large
5. Verification of Basic Physical Laws in the small	• Precise measurement of gravitational constant • Precise measurement of equivalence of inertial and gravitational mass

E-0988

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MILITARY AREA

AEROSPACE FORM 4253

V-87652

The general pattern of international developments in the time period indicates increasing stress with resultant tactical conflicts at an ever-increasing pace, as well as a continuation of ideological conflict among major nuclear powers.

COMPLEX PATTERN OF INTERNATIONAL RELATIONS
1980 - 2000

1. 5 REGIONAL GREAT POWER CENTERS (3 NUCLEAR). -- SURPLUS AREAS. REMAINDER OF WORLD POLITICALLY AND ECONOMICALLY FRAGMENTED -- DEFICIT AREAS.

2. ECONOMIC AND CULTURAL STRESS AMONG GREAT POWER CENTERS.

3. NUCLEAR FORCES CAPABLE OF MULTI-REGIONAL OVERKILL. NUCLEAR CONFLICT DETERRED. NON-NUCLEAR CONFLICT LARGELY UNINHIBITED.

4. VERY SEVERE STRESS IN DEFICIT AREAS, PRODUCING VARIED LOW LEVEL CONFLICTS, SEVERAL PER YEAR.

5. MULTI-PARTY MANEUVERING FOR ADVANTAGE -- ECONOMIC, POLITICAL, IDEOLOGICAL.

V-87653

The major goals for the U.S. are indicated: to maintain a credible strategic deterrence, and to increase the tactical capability to the point of credible "tactical deterrence"; and to win tactical conflicts rapidly and decisively if forced to enter. The major problems anticipated for the U.S. will be to stay out of most of the local/tactical conflicts, of which perhaps 1/year are anticipated, and to have enough information to decide on which ones and when to enter.

MAJOR U.S. GOALS IN INTERNATIONAL RELATIONS 1980-2000	GENERAL IMPLICATIONS FOR MILITARY OBJECTIVES
1. MAINTAIN BALANCE OF POWER AMONG REGIONAL GREAT POWER CENTERS. DEVELOP "RULE OF CONCURRING "MAJORITY."	1. MAINTAIN STRATEGIC NUCLEAR STALEMATE.
2. EXPAND MUTUALLY BENEFICIAL ECONOMIC RELATIONS AMONG REGIONAL GREAT POWER CENTERS TO INCREASE OVERALL PRODUCTIVITY.	2. ONLY INCIDENTAL RELATION
3. AVOID GREAT POWER CONFRONTATION IN MINOR CONFLICTS.	3. MILITARY RESPONSES IN LOW LEVEL CONFLICT TO BE NON-ESCALATORY.
4. GENERALLY AVOID DIRECT U.S. MILITARY INVOLVEMENT IN LOCAL CONFLICTS. HOWEVER, UPHOLD U.S. INFLUENCE AND LEADERSHIP BY THE CREDIBILITY OF INTERVENTION WHEN REQUIRED.	4. ATTAIN "TACTICAL" DETERRENCE IN LOW LEVEL CONFLICT BY CAPABILITY OF ELITE TACTICAL FORCE IN BEING, WITH PROPER SUPPORT FROM INFORMATION GATHERING SYSTEMS.

The projected U.S. military objectives in the time period are listed on the facing page. The detail development of the goals is found in Appendix A.

PROJECTED U.S. MILITARY OBJECTIVES 1980 - 2000

A. STRATEGIC

1. DETERRENCE BY ASSURED DESTRUCTION
2. STRATEGIC ARMS CONTROL
3. CREDIBLE DETERRENCE OF P.R.C.
4. NON-PREJUDICIAL AVOIDANCE
5. N^{th} COUNTRY STRATEGIC WEAPONS
6. ANTI-BLACKMAIL
7. FLEXIBLE NUCLEAR RESPONSES
8. SMALL ATTACK DAMAGE AVOIDANCE
9. STABILIZING ABM
10. READINESS
11. DUAL ROLE

B. GENERAL PURPOSE

12. NON-ESCALATORY CRISES RESPONSE
13. ANTI-PARAMILITARY OPERATIONS
14. SECURE BORDERS
15. NO HOSTILE BASES IN HEMISPHERE
16. TACTICAL DETERRENCE
17. NON-PREJUDICIAL AVOIDANCE
18. TACTICAL WAR CAPABILITY

Pages 32 through 37 present a summary of the space functions in support of the military objectives for the time period of interest. They are omitted for security classification reasons.

With the above brief treatment of the functional requirements for space as background, this section treats the projections of technology which will shape the limits of what we could do in space in the next 25 years. There is generally not an intended relationship between what we could do and what we should do, which is represented by the functional requirements treated in the last section, although by the very nature of the exercise and since it was performed by the same people, there is a correspondence. That correspondence will be addressed later in the report. Many of the technology projections that will be discussed are based on knowledge of the status of military and civilian technology today and understanding of the laws of physics, rather than on any particular technique for forecasting such as trend extrapolation, normative techniques, or similar techniques. They represent an almost intuitive approach to what will probably be able to be done given today's technology, research directions, and the intent to move forward. There are no budget limitations imposed on any of the technology areas which will be discussed, and the assumption is made that if an interesting and high payoff area is identified, it will be pushed at whatever rate it can meaningfully advance, independently of any other factors.

It is for the above reasons that some of the projections of techniques may appear "wild" to those struggling to apply today's technology to satellites which must operate reliably and predictably. Nonetheless, as will be seen in this section as well as in the initiatives, such "far out" technologies can result in some initiatives of impressive performance.

ADVANCED TECHNOLOGY PROJECTIONS

B-115

The previous areas of high leverage of technology are related on the facing page to the general capabilities implicit in their application. Large mirrors and large antennas, assembled or fabricated in space and functionally initialized by men, will make possible the detection of very tiny signals from very far away by means of large apertures. The tight beam collimation possible, together with high energies and lasers will make possible the delivery of energy far away at the speed of light, for a host of commercial energy delivery applications as well as speed-of-light tight-beam weaponry. All such applications take precision pointing and tracking, and some of that may well require a manned operator in the loop, whether he is resident in space or on the ground.

Remote sensing of small signals far away has application to reading out battlefield sensors or border intrusion sensors, and for detecting the presence of missiles, satellites, aircraft, and ships. Much of the data is buried in background or noise the extraction of which, together with the simultaneous processing of many channels, will require the LSI processors; and the sensors will require mosaic charge-coupled devices for high area search rate. New detector techniques in the 100 to 1000 or 10,000 micrometer quasi-optical region could make these capabilities all-weather. Furthermore, the ability to employ low energy lasers aboard satellites as local oscillators can make optical heterodyne techniques a reality, resulting in very narrow spectral acceptance bands and rejection of background.

Many of the sensory techniques, particularly so for those of long-wave length, require cooling to cryogenic temperatures to reduce internal noise, mandating long life, closed-cycle refrigerators.

The efficient generation and delivery of energy will require development of lightweight, efficient solar cells. The placing in orbit and maneuvering of all of the systems so configured will require new propulsion techniques which have a higher ISP; and some military needs for survival under attack will need higher thrust simultaneously. These capabilities will be greatly expanded in the several figures to come, which present projections of current-day technology in some of these high-leverage areas.

HIGH LEVERAGE NEW TECHNOLOGY IMPLICATIONS

DESIRED CAPABILITIES	REQUIRED TECHNOLOGY
COMMUNICATIONS/NAVIGATION - Detection of Small Transmitters Far Away - Small, Cheap, Long-Life User Equipment - Large Scale Multiple Access/Anti-jam - Remote, Inexpensive Position/Velocity Indication - Undersea - Space Communications - Survivability of Function SURVEILLANCE - Passive Detection of Equipment, Men, Action - Active/Bistatic Detection of Equipment, Men, Action - Operations in Day/Night/All Weather - High Volumetric Search Rate at High Resolution - Undersea/Sea/Space/Air Detection - Multi-Spectral Operations WEAPONS/SUPPORT - Tight Beam, Speed-of-Light Weapons - Electronic Beam Steering - Energy Delivery - Environment Modification - Remote Designation/Guidance	• Large Optics and Mirrors • Large RF/Microwave Antennas • Manned Fabrication and Assembly • Large, Economical Transportation Systems • High Power/Energy; Efficient, Lightweight • Lasers: Radar; High Energy/Power • Precision Pointing and Tracking - Teleoperator Acquisition • LSI Computers/Processors • Mosaic/CCD Focal Planes • New Detectors - 100 - 1000 μm; Heterodyne • Cryogenic Refrigerators • New Propulsion - Ion; Fusion, Solid Hydrogen; Rock Linac

In thinking about future space applications, we consider some areas of technology which are ripe for exploitation and which could have high leverage in moving space programs in new directions. Eight such technology areas are shown on the facing page.

Space is the natural environment for very large structures and for complexes which need much space between elements. The extensive space is there for the asking. But, in addition the zero-g environment permits the use of weak structural elements and flimsy surfaces so that but little mass of materials is required even in very extensive structures. We see the possibility of antennas or reflectors which are made of thin film material only a few milligrams per cm^2, in sizes of several kilometers. If even greater extension than a few kilometers is required, as in long base interferometers, the elements can be widely separated and held in good relative position not by rigid material connections, but by an information web controlling positioning devices. In general in our projected applications, we have included many which just could not be accomplished without very large structures or arrays.

Past space applications have been restricted to relatively low energy use, because of the difficulty of putting massive energy supplies in space. But energy generated on the ground in very large amounts can be transported through space by laser or microwave beams. Furthermore solar energy itself is abundantly available in space, particularly if we use very large area collectors. Power management methods will also develop so that very high pulsed powers $\sim 10^{12} - 10^{14}$, watts can be handled at moderate average power levels. We conclude that high energy usage or high peak power requirements will not in the future rule out as impractical particular space applications.

Lasers in all forms will be developed for terrestrial science and technology applications - a highly developed technology in the laser field will then be ready for space applications, including lasers and masers of all frequencies from the ultra-violet to the microwave, high beam quality, very narrow frequency spread, and variable but accurate frequency control.

Data processing is now a pacing problem in some space concepts. But advances in solid-state electronics, with application to computer technology, and the development of analog or digital parallel processors will continue at a rapid pace as driven by terrestrial requirements - these advances will solve many of the problems of data processing in space applications.

The next area is that of the so-called gap between the microwave and the infrared, somewhere between 10 and 10,000 μm. This is a spectral region which is largely unexploited, and yet has inherent capabilities to penetrate some clouds, fog, and haze. In combination with lasers at these wavelengths, the possibilities for all-weather "optical" systems with smaller radiating structures than those of radar can become a reality.

The next technology area is that of controlled nuclear explosions not only for power generation by fusion, but in application to propulsion of space vehicles, both by large-scale explosions and by small-scale laser initiated fusion explosions. Such techniques can probably offer high-energy densities per unit mass and per unit cost investment for energy and propulsion applications. In the last category is an area which is largely unexplored at the moment, which deals with pehnomena which depend upon the cooperative action of many particles; for instance, plasma interactions, accelerator applications.

The first five of these technology leverage areas are explored and applied in the initiatives which are presented in this report. The last three, even though they probably have as much potential for application in space, are as yet unexploited in our initiatives. Follow-on exercises of this type should make more of an attempt to explore those phenomena.

LEVERAGE AREAS

- VERY LARGE STRUCTURES
- VERY HIGH ENERGY/POWER
- LASERS
- MICROELECTRONICS/COMPUTERS
- ANALOG PARALLEL PROCESSORS
- INFRARED-MICROWAVE GAP
- CONTROLLED NUCLEAR EXPLOSIONS
- COOPERATIVE MODE PHENOMENA

The first area of technology which is projected is that of large RF or microwave communication antennas. The numbers on the figure indicate the gain at S-band or C-band or X-band, the number of simultaneous beams that have been attained from a single reflector, the number of channels in a typical communications satellite, the output power per channel, the total output power, the number of accesses or number of voice equivalent communication links capacity, and the figure of merit of a receiver in space with that size antenna and an appropriate front end.

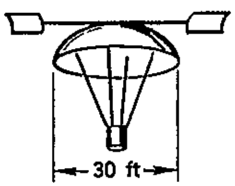
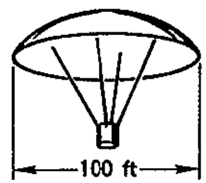
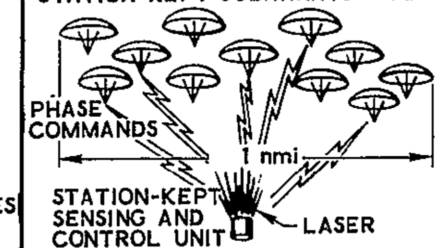
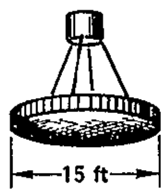
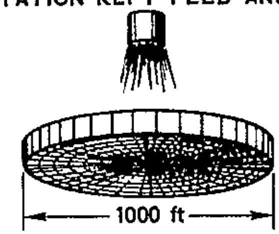
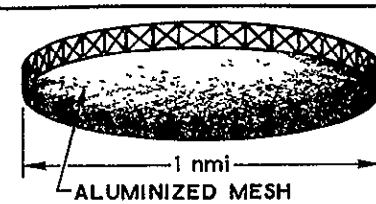
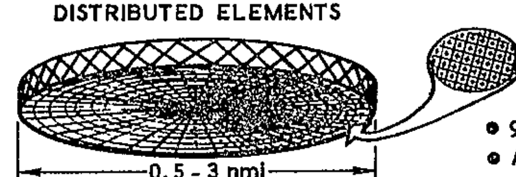
The current state-of-the-art is 30 feet. This capability can readily be increased in the next few years to single-dish reflectors of the order of 100-foot diameter. To go much beyond that involves enormous penalties in structure to hold the figure of the reflector. In the far term, instead of making one very large dish, a technique has been conceived in which a number of small sub-arrays or sub-elements, (either dishes, individual dipoles, or collections of dipoles) are coarsely stationkept with respect to each other and a central stationkept sensing and control unit. A small laser radar with very short pulses aboard the control unit would measure the range to each element to an accuracy of a small fraction of the RF wavelength being used, and then would command the phase of the feed in each sub-array to cause in-phase reception or in-phase generation of energy by the elements of the array. This way a controlled phase front can be generated regardless of the actual physical figure of the sub-arrays without requiring tight physical tolerances with their attendant heavy structure. The spacing of the elements can be non-uniform to avoid grating lobes, and the array can be either quasi-filled or thinned. With this technique, extremely large size, gain, directivity, and figure of merit can be attained.

The second technique which is shown is that of multibeam lens antennas, which are well adapted for generating a number of beams simultaneously, each with the same gain as given by the main aperture. One mechanization is that of multiple feeds each illuminating a bootlace lens or dielectric lens antenna. The state-of-the-art capability for the next five or ten years is antennas of the order of 15-foot diameter in space. Designs exist for five-foot antennas with 100 beams. This technology can be extrapolated to sizes in the order of 1000-foot diameter, even though the lenses become extremely heavy. In such sizes, the feed horn arrays could be stationkept rather than physically trussed to save weight.

A third application of space RF structures is that of passive reflectors, mechanized by a trussed mesh or by a stretched thin film membrane with aluminized conductors or surface coatings. Reflectors or diffractors are feasible, forming either simple mirrors or gratings whose direction of beam transmission or reflection depend on the frequency. Then beam scanning can be accomplished by frequency modulation. Diameters of one mile will be attainable with such techniques.

Lastly, phased arrays can be built with their receiving or transmitting elements distributed throughout the extent of a single large structure (or for that matter, smaller structures), forming agile beams or generating large amounts of power. The figure of merit of these structures in a receiver mode can be very much greater than that obtainable today, and the energy transmission capability can be huge because of the large sizes which can be assembled in space.

Large RF/Microwave/Communication Antennas

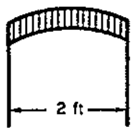
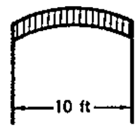
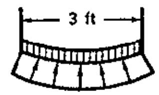
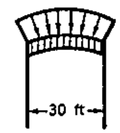
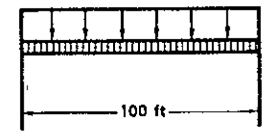
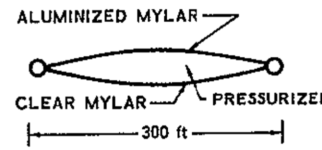
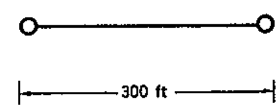
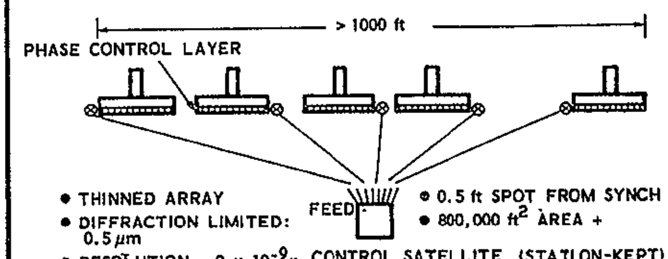
CURRENT	NEAR TERM	FAR TERM
DISH REFLECTORS  • 50 dB GAIN (c) • 20 BEAMS • 24 CHANNELS • 20 W/CHANNEL • 500 W TOTAL • 10^4 ACCESSES • 15 dB/°K	 • 64 dB GAIN (x) • 50 BEAMS • 50 CHANNELS • 200 W/CHANNEL • 10 kW TOTAL • 5×10^4 ACCESSES • 37 dB/°K	STATION KEPT SUBARRAYS - SELF-ADAPTIVE  • PHASE CONTROLLED BY MASTER STATION FOR CONSTRUCTIVE INTERFERENCE AT DETECTOR • COARSELY STATION KEPT • ARBITRARILY LARGE SIZE, GAIN, POWER, G/T
MULTIBEAM LENS	 • 50 dB GAIN (x) • 100 BEAMS • 100 CHANNELS • 200 W/CHANNEL • 20 kW TOTAL • 10^5 ACCESSES • 22 dB/°K	STATION KEPT FEED ARRAY  • 88 dB GAIN (x) • 1000 + BEAMS • 1000 + CHANNELS • 1 kW/CHANNEL • 1 MW TOTAL • $>10^6$ ACCESSES • 70 dB/°K
PASSIVE REFLECTORS		 • PASSIVE REFLECTOR OR PASSIVE DIFFRACTOR • 30×10^6 ft^2 AREA • $>10^{10}$ WATTS POWER RELAY CAPACITY
PHASED ARRAYS		DISTRIBUTED ELEMENTS  • DISTRIBUTED OUTPUT TUBES • DISTRIBUTED DIPOLES • DISTRIBUTED RECEIVERS • 90-110 dB GAIN (x) • AGILE BEAMS • 10,000 MW TOTAL • 83 dB/°K

The figure on the facing page presents technology projections for optical components. In the current state of the art, two or three feet in diameter is the maximum for diffraction-limited optics. In the near term, that is, in the next five or ten years, technology can very readily support 10 or 12-ft diameters in single-structure passive mirrors, and probably three to five feet in mirrors with active figure control. The active figure control, implied by the arrows in the figure, is accomplished by applying pressure to the back plate of the mirror either by piezo electric or hydraulic actuators controlled in an adaptive manner by sensing the performance of the optics. Technology development for space mirrors in the next 25 years may permit diameters in the order of 30 to 100 feet with active figure control. One hundred feet diameter mirrors, diffraction limited at 0.5 μm have a resolution of 10^{-8} radians, corresponding to a resolution of five feet on the ground from synchronous altitude--an enormous capability increase over the 250-foot resolution we can do today.

Since the above mirrors will undoubtedly be heavy, a second technology has been forecast, represented by thin-film mirrors or collectors. In the second row we see that by stretching a thin aluminized mylar film over a frame, a very light-weight mirror of large size could be made. Single films give plane mirrors. Two films attached at the outer edges with gas between them will take on a spherical figure resulting in a focusing mirror, if one film is clear and the other one is aluminized. Designs for flat mylar mirrors have existed for a number of years, but none have yet been built in space. It is quite clear from the inhomogeneity of the film manufacture that, in sizes in the order of 300 to 1000 feet, diffraction-limited performance will not be attained. On the other hand, for applications where quality is less important than aperture, these mirrors have the potential for extremely lightweight per unit collecting area.

In the last row of the last column we present a far term possiblity to extend the capability from that of single mirrors, whether solid or film type, to that of an array of as large a diffraction-limited aperture as desired, without requiring that tolerances of a fraction of the wavelength be held over the dimensions of the array. The technique is not to control the wave-front from the mirror physically, but to control it electronically. Each of the units in the array is an independent satellite, coarsely stationkept. A small control sub-satellite will measure, with a small laser, the range, position, and attitude of each of the sub-satellites. Each satellite mirror will be coated with a material whose index of refraction can be controlled in some manner, say, by the application of electric fields or flooding with laser energy, such that the phase of light reflection off that mirror can be changed by command by the control satellite. By sensing at the control satellite some of the reflected energy from each of those mirrors, one can command phase changes to give constructive interference, regardless of the physical position of the reflectors themselves. Although such a technology needs development, there is nothing in physics or in the application of control techniques that would seem to prohibit it. With such techniques, thinned optical arrays at least 1000 feet in diameter should be obtainable, with the further limits simply not known. A 1000-foot thinned array would have a resolution of 0.5 ft on the ground from synchronous altitude. Applications of such technology are clearly suggested by the above performance numbers.

Large Optics/Mirrors

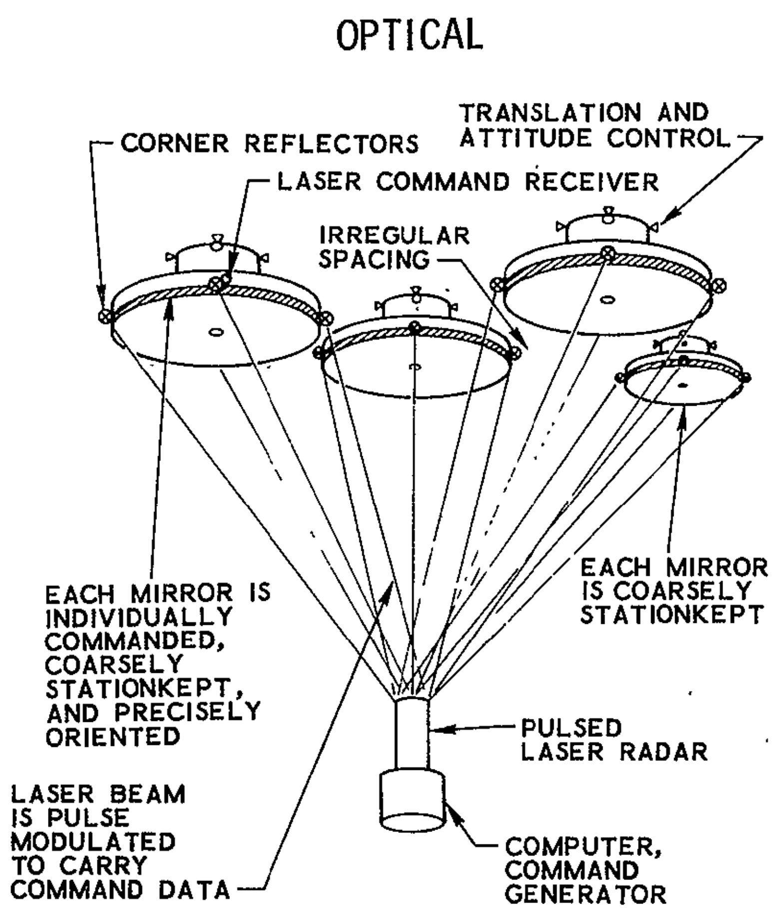
	CURRENT	NEAR TERM	FAR TERM
SINGLE STRUCTURE, THICK	PASSIVE  • DIFFRACTION LIMITED: 0.5 μm • RESOLUTION = 2×10^{-6} r • 240 ft SPOT FROM SYNCH • 3 ft^2 AREA	PASSIVE  • DIFFRACTION LIMITED: 0.2 μm • RESOLUTION = 2×10^{-7} r • 50 ft SPOT FROM SYNCH • 80 ft^2 AREA ACTIVE FIGURE CONTROL HIGH TEMPERATURE MIRROR 	ACTIVE FIGURE CONTROL  • DIFFRACTION LIMITED: 0.5 μm • RESOLUTION = 6×10^{-8} r • 16 ft SPOT FROM SYNCH • 700 ft^2 AREA  • DIFFRACTION LIMITED: 0.5 μm • RESOLUTION = 2×10^{-8} r • 5 ft SPOT FROM SYNCH • 8000 ft^2 AREA
THIN FILM			TENSIONED THIN FILM   • 1000 X DIFFRACTION LIMIT • RESOLUTION = 1.3×10^{-5} r • 1600 ft SPOT FROM SYNCH • 70,000 ft^2 AREA
MULTIPLE STRUCTURE SELF-ADAPTIVE			STATION KEPT SUBSATELLITES, SELF-OPTIMIZING  • THINNED ARRAY • DIFFRACTION LIMITED: 0.5 μm • RESOLUTION = 2×10^{-9} r • 0.5 ft SPOT FROM SYNCH • 800,000 ft^2 AREA +

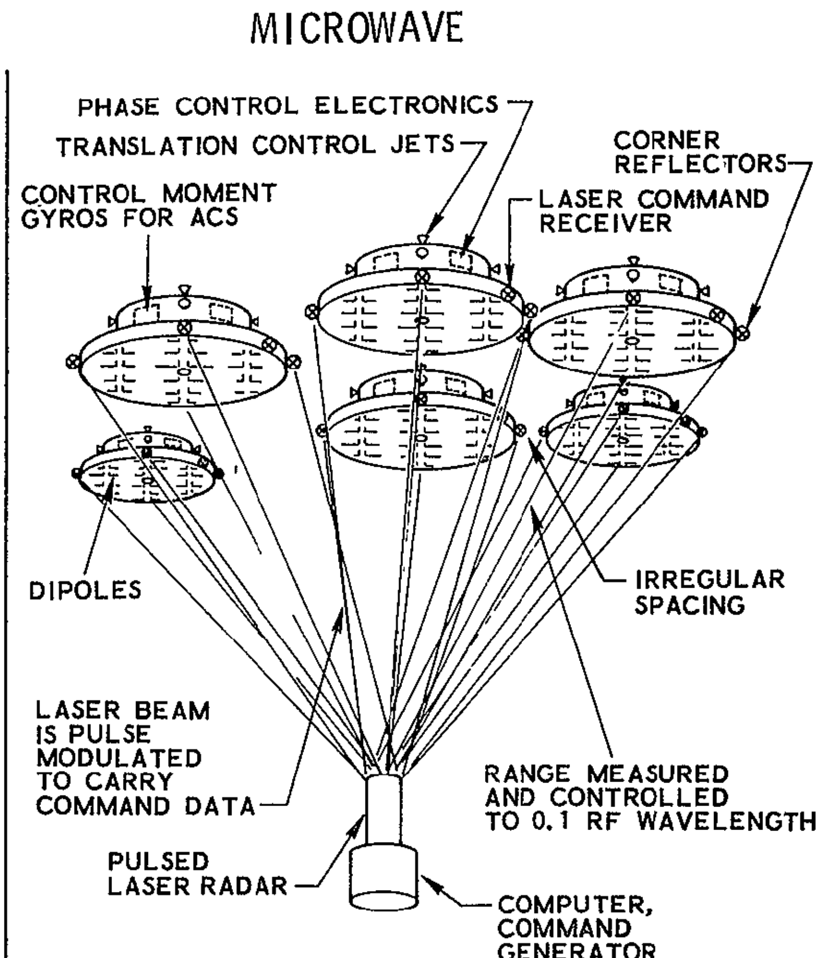
B-116

The facing figure illustrates in a little more detail the self-adaptive array technique for configuring large arrays without requiring physical precision in the alignment of the elements In the microwave region the technique for controlling the phase of the transmissions or receptions is well understood. It is done under the control of the master station, which measures the relative position of the elements to a fraction of the RF wavelength, and commands phase shifters in each element. In the optical region, there are no techniques yet to measure the position to a fraction of an optical wavelength, however the phase control could be accomplished by commanding the refractive index of special coatings over the mirrors (by electric field excitation for instance), which will change the phase of reflection in such a way and with adaptive control so as to result in constructive interference addition at the stationkept central location. Additionally, the laser radar can measure the attitude of each unit very precisely, and serve as a remote attitude reference unit, using the laser itself as a command link to command attitude control of each unit, translational position of each unit, or both.

It is the above techniques which will be applied in many of the initiatives for forming extremely large arrays and mirrors in space.

Self-Adaptive Array Techniques

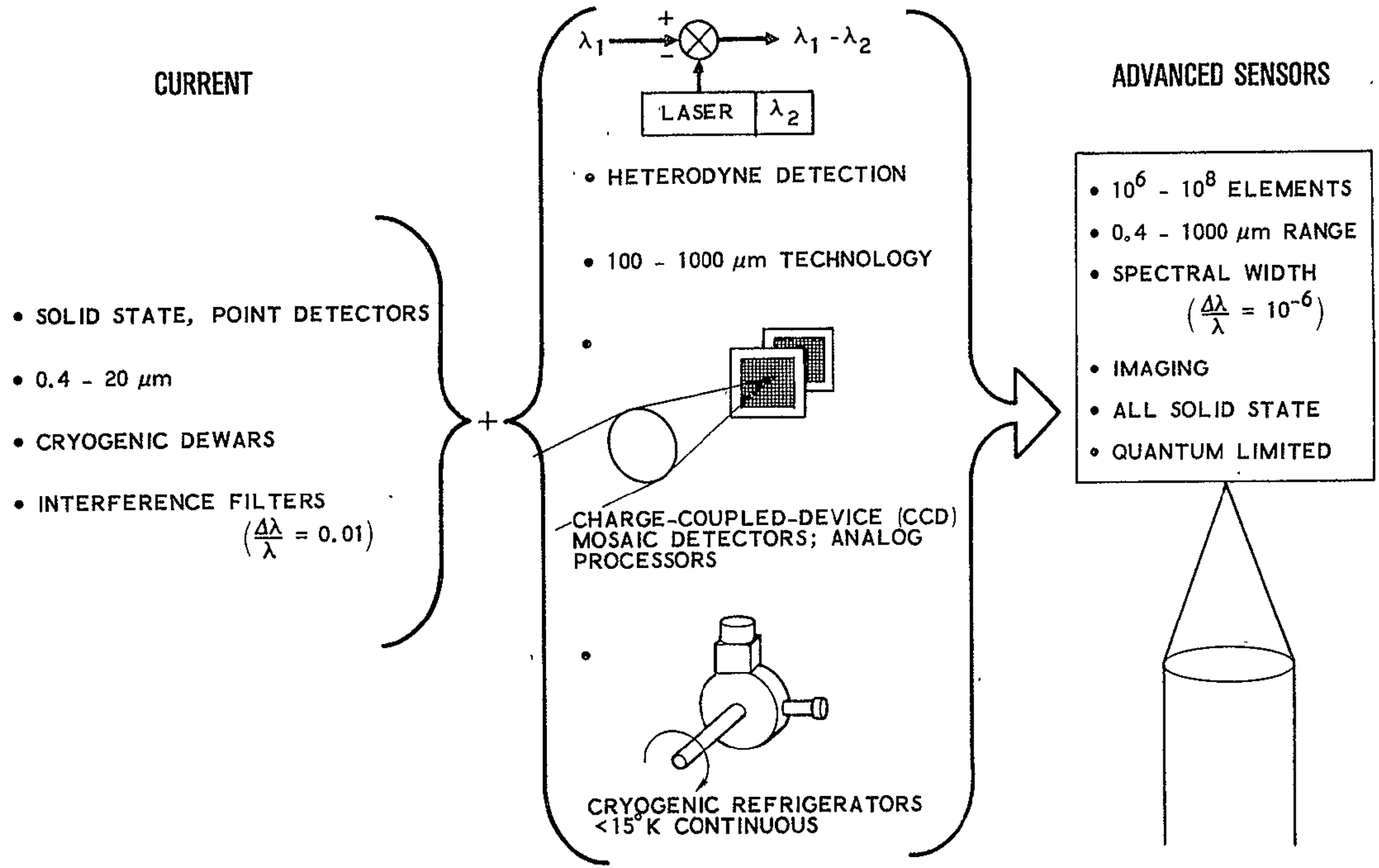




B-117

The current state-of-the-art of focal plane components consists of solid-state point detectors sensitive to the wavelength region between the ultraviolet and 50 μm. They are cryogenically cooled if required by expendable cryogen supplies for a very limited lifetime. Multipliers and image tubes with high sensitivity exist in the visible and near IR. Incoming wavelengths can be spectrally filtered to about one percent of the base wavelength. With the addition of the high leverage technology advances shown, sensors will evolve which have solid-state imaging mosaics of a large number of detector elements with charge coupling, sensitive in any spectral range, with very narrow spectral acceptance regions for rejection of backgrounds, with charge coupled analog processors incorporated into the focal planes, and all cooled with long-life refrigerators. The very narrow spectral widths will be ideal for sensing laser illumination. These advances will make possible greatly improved sensitivity and coverage rate in sensing systems, and are applied in many of the initiatives in this report.

Focal Planes/Detectors

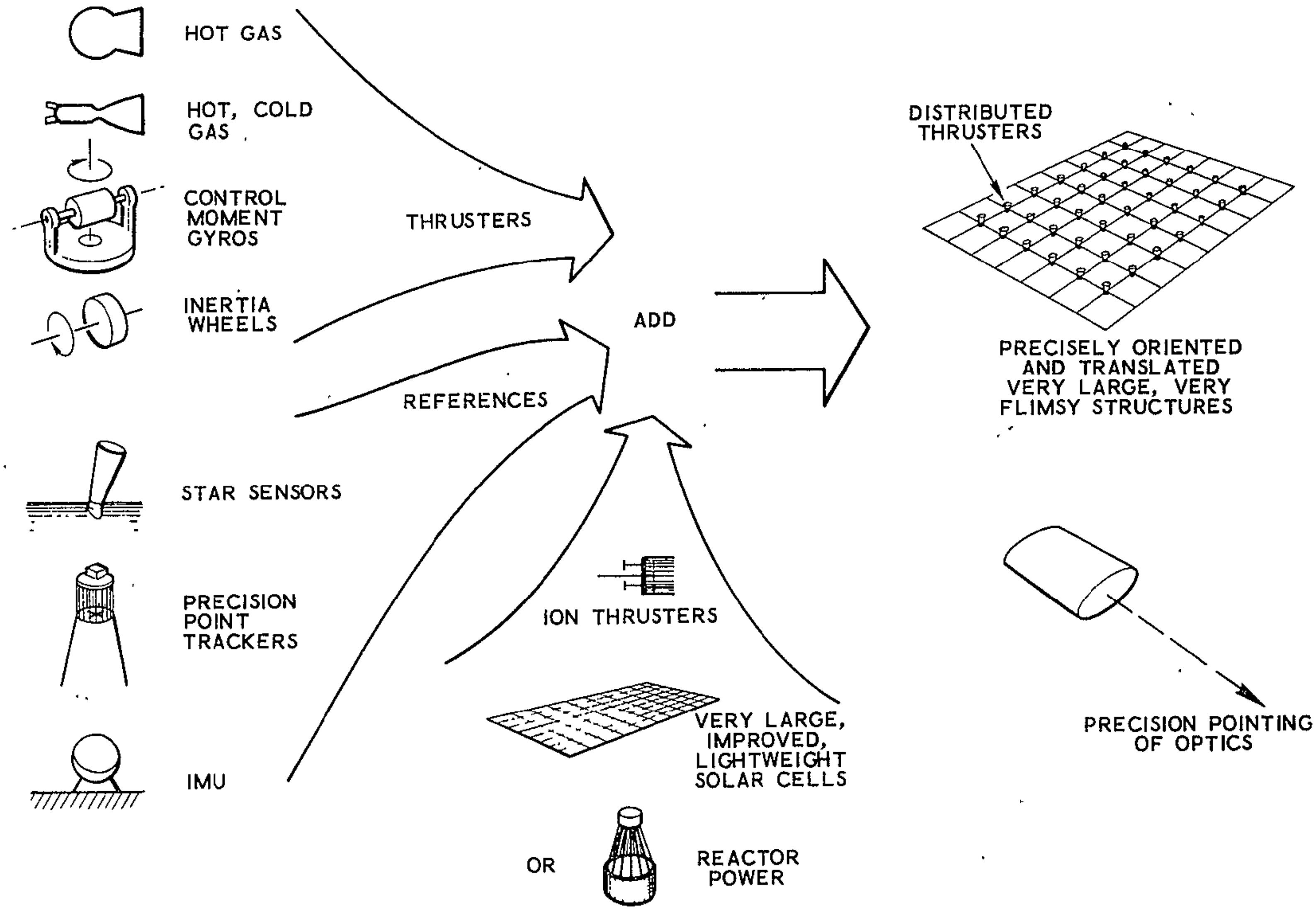


B-118

The facing figure addresses techniques for the precise translation and orientation of some of the large arrays forecast in the previous pages. To avoid extremely heavy structures, flimsy construction very much akin to a piece of paper can be devised and assembled in orbit, but conventional attitude control with a few thrusters on the periphery of the structure such as in common practice today will not be adequate. Distributed thrusters operating in concert will be required. Tiny resistojets or ion thrusters, and lots of electrical energy to operate them, will be needed. Such technology, together with the attitude reference and sensing techniques inherent in the focal planes mentioned previously, will result in a capability to precisely point and translate even very large and flimsy structures or sub-elements of very large arrays.

The next several pages project a forecast of typical applications of the advanced technology; and the rest of the report following the forecast will be devoted to a treatment of specific initiatives in the military and civilian area.

Precise Orientation Control



Pages 54 through 59 present forecasts of possible advances in the three key technological areas of: (1) optical observation; (2) RF/microwave/ communications; and (3) weapons and support. They are omitted for security classification reasons.

The previous applications and forecasts were based on ambitious growth in the high leverage technology areas identified. Even if such advances in technology do not occur in this time period, there will be advanced satellite systems based on more conservative extrapolation of today's technology, which will take place as product improvements, block changes, or growth versions of today's satellites; as well as new space systems currently in the programming stage. It is these advances which are treated in the next several pages.

In the civilian communications area, the current Intelsat IV will be replaced by the Intelsat IVA, which will have the advantages of some frequency reuse and higher circuit capability, as well as domestic Comsats and TV broadcast satellites. In the surveillance area, the earth resources satellites will be improved for more resolution, more spectral channels; and more restricted systems will be placed in geosynchronous orbit. Sea state will be measured directly, as will low-altitude winds and other phenomena.

NEAR-TERM GROWTH OF CURRENT PROGRAMS
CIVILIAN

FUNCTION	TYPICAL CURRENT	NEAR-TERM GROWTH
1. Communications	INTELSAT IV, ANIK	INTELSAT IV A
• Trunking	- operational - 10^4 circuits	- multiple beams - frequency reuse - more capacity - FDMA/TDMA
• Small User	ATS-F - experimental - van terminals - TDMA	MARISAT, AEROSAT - VHF/UHF - maritime, aircraft service
• Data Relay	--	TDRS - experimental systems
2. Surveillance		
• Land	LANDSAT (ERTS) - multispectral imaging	- improved resolution - more spectral bands - more storage/TDRS readout
• Ocean	--	SEASAT - ocean physics, sea conditions

E-0991

In the meteorological area, there will be more operational flights, as well as continuing improvement for finer resolution, more frequent coverage, and more spectral coverage for finer diagnostics of the weather systems. There will be a military navigation satellite (the Global Positioning System) developed which will replace the transit system as the primary military navigation system for global use for mobile users, and it will also accommodate civilian users. The current experiments in navigation on the ATS-F may result in further tests and experiments. There will be several planned payload improvements over the current geodetic, geographic, and earth physics satellite systems.

NEAR-TERM GROWTH OF CURRENT PROGRAMS
CIVILIAN

FUNCTION	TYPICAL CURRENT	NEAR-TERM GROWTH
3. Meteorology	NOAA, NIMBUS, SMS	- multispectral - microwave radiometry - improved sensitivity - lower cost
4. Navigation	none	Military will provide.
5. Earth Physics	ANNA, GEOS, PAGEOS, SECOR	- SEASAT (sea conditions) - LAGEOS (laser geodetic sat) - GRAVSAT (gravity gradiometer) - MAGNETIC MONITOR (mag field)

Pages 64 through 69 present near-term growth projections for the military program categories of: (1) communications; (2) surveillance; (3) meteorology; (4) navigation; (5) earth physics; (6) space combat; (7) space-space weapons; (8) space-ground weapons. They are omitted for security classification reasons.

E-0995

The following section presents the catalog of initiatives assembled to date. By initiative is meant an opportunity for a system concept that is designed to have a particular utility or perform a particular function, but does not exist today. The catalog of initiatives was generated utilizing only basic physical principles and the time frame of interest as limiting constraints. Each initiative is treated as though there are no budgetary limitations, no policy limitations, no current military or civilian doctrine limitations, and no resource limitations, and as though it were accepted as a desirable and important project. All initiatives are independent of each other.

INITIATIVES

E-0965

The initiatives in the catalog are organized by gross function, including Observation, Communications, Support, and Weaponry, and by whether they are civilian or military. The organization of the initiatives is shown on the facing page in a functional sense.

ORGANIZATION OF INITIATIVES

	OBSERVATION	COMMUNICATIONS	SUPPORT	WEAPONS
CIVILIAN	Resources/Surveys Pollution/Mapping Energy Monitors International Sensors Traffic Sensors	Emergency/Police Government Services Personal Services International Navigation	Energy Delivery Environment Control Traffic Control Markers/Aids	
MILITARY	Strategic Sensing - Missiles - Aircraft Tactical Sensing - Battlefields - Other	Strategic Tactical Navigation	Guidance/Navigation Environment Control Logistics Energy Delivery	Offense - Strategic - Tactical Defense - Strategic - Tactical

Pages 74 through 79 present listings of three initiative categories: (1) optical observation; (2) RF/microwave/communications; and (3) major weapons and support, separated into near-term and far-term opportunities. They are omitted for security classification reasons.

A simple coding scheme is used for identifying the initiatives. The first letter "M" or "C" designates whether it is military or civilian. The second letter, "O", "C", "S", or "W" designates whether it is Observation, Communication, Support, or Weaponry. A number then represents the number of the initiative within each subcategory.

The next four pages list the index of the initiatives, in the order of the appearance of their data sheets in this report.

A number of initiative concepts have been identified functionally, but not yet quantitatively defined. They are included in the index and identified by an asterisk, but are not included in the initiative data sheets which follow.

INDEX TO INITIATIVES

* - To be supplied

INDEX TO INITIATIVES (CONTINUED)

* - To be supplied

INDEX TO INITIATIVES (CONTINUED)

MILITARY - COMMUNICATIONS

INDEX TO INITIATIVES (CONTINUED)

INDEX TO INITIATIVES (CONTINUED)

E-1001

The facing page is a sample format used in presenting the data on the initiatives in the catalog. Each initiative is described on one such format sheet. Each initiative has had sufficient preliminary analysis to grossly define the system concept, to estimate the satellite gross weights and sizes; and to define the major performance parameters of key space and ground elements. A pictorial is presented of the function to be performed.

A brief statement is made of the purpose of the initiative and of the reasons why such an initiative might be useful. The concept is very briefly described. The characteristics of the satellite are summarized in terms of gross weight, size, and raw power on orbit. The orbit characteristics are given. The number of satellites required to form an active constellation of the calculated performance are given. The design or useful life on orbit and the servicing period required are also estimated. The time frame during which the earliest conception of each initiative could materialize is estimated. The cost to the first operational capability including R&D, investment in the first operational units, and the required booster costs are estimated. The performance is described in terms of those numbers most relevant to the utility.

For each initiative concept, the building block requirements (such as Shuttle or Large Launch Vehicle, upper stage or Tug or SEPS or other orbital vehicle) are stated and any special requirements on the subsystems or technology are identified. If there are no special requirements above and beyond today's technology, those sections are left blank.

- PURPOSE

- RATIONALE

- CONCEPT DESCRIPTION

- CHARACTERISTICS
    - WEIGHT
    - SIZE
    - RAW POWER
    - ORBIT
    - CONSTELLATION SIZE
    - LIFE/SERVICING PERIOD
    - TIME FRAME
    - IOC COST

- PERFORMANCE

- BUILDING BLOCK REQUIREMENTS
    - TRANSPORTATION
    - ON-ORBIT OPERATIONS
    - SUBSYSTEMS
    - TECHNOLOGY
    - OTHER

SAMPLE

CO-1. - Advanced Resources/Pollution Observatory

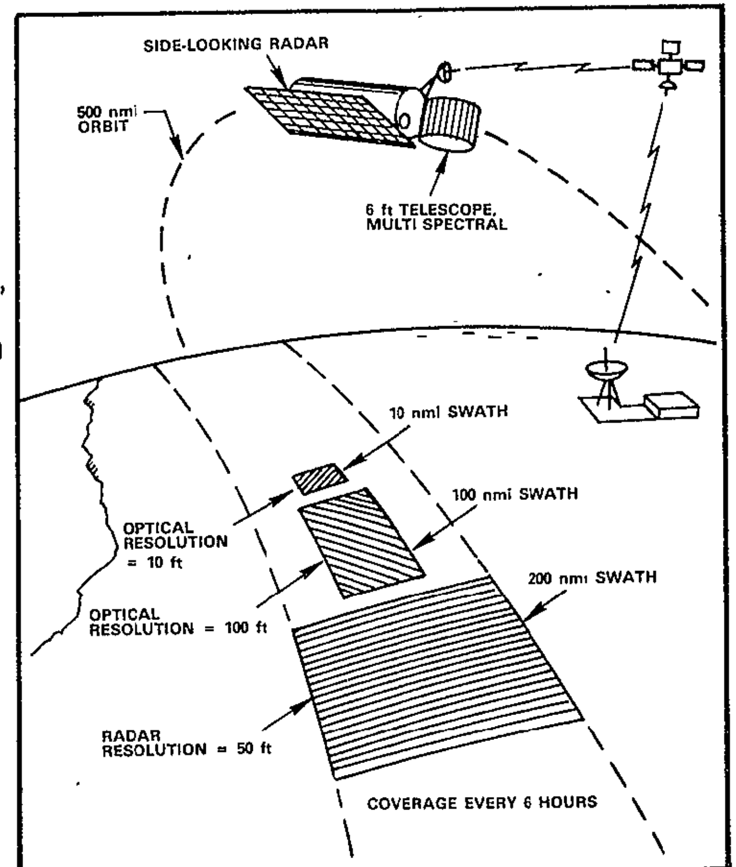
The intent of this initiative is to provide an increased capability over that currently obtained from the Land-Sat earth resources satellite series. By combining side-looking radar, a large aperture telescope with visible light and infrared multispectral coverage, and a data relay readout, both fine and coarse resolution varying from 10 -100 feet could be made available in all weather, in real time globally. Laser or EHF links would be used for real-time data distribution to worldwide users. Even though the satellite is heavy, this is a near-term initiative opportunity, and is qualitatively anticipated by one or more components of the 1973 NASA mission model. This initiative could combine many other functions, such as sea-state surveillance, or astronomical observations on a time-shared basis.

ADVANCED RESOURCES/POLLUTION OBSERVATORY (CO-1) (U)

- **PURPOSE**
  To provide high quality, multispectral earth resources and pollution data.

- **RATIONALE**
  Integrated ERTS-like system, real-time data distribution to world-wide users, active sensors needed.

- **CONCEPT DESCRIPTION**
  Active and passive sensors, large aperture, high, medium, and low resolution imaging obtained in multispectral region and radar. Data disseminated by laser link through relay satellite.



- **CHARACTERISTICS**

• WEIGHT	30,000 lb
• SIZE	10 x 60 ft
• RAW POWER	12 kW
• ORBIT	500 mi sun synch.
• CONSTELLATION SIZE	4
• LIFE/SERVICING PERIOD	10/3 Years
• TIME FRAME	1985
• IOC COST	710 M

- **PERFORMANCE**
  Resolutions varying from 10 - 100 ft obtained world-wide.

- **BUILDING BLOCK REQUIREMENTS**

• TRANSPORTATION	Shuttle
• ON-ORBIT OPERATIONS	Shuttle attached manipulator
• SUBSYSTEMS	Guidance and navigation; attitude control; transmitter
• TECHNOLOGY	Large radar antenna; high power tubes and modulator; LSI data processor
• OTHER	None

CO-2 - Forest Fire Detection (U)

The intent of this initiative is to detect forest fires by their infrared emission while they are still small enough to be checked without major loss of resources, property, or life. Advanced infrared mosaic detectors, coupled with 120-inch optical receiver, can result in a sensitivity to detect fires as small as 10 feet x 10 feet buring area, and to pinpoint their location within 300 feet anywhere in the U.S. once every 2-1/2 minutes. In addition to pinpointing fires at a very early stage, surveillance can be maintained automatically over large fires so that hot spots, perimeters, new flare-ups, and progress of fire-fighting efforts may be determined and controlled remotely in real time. This is a straightforward extrapolation of today's techniques, requiring only developments of the large mirror, and a CCD focal plane. A single satellite suffices for real-time control and detection over the entire United States.

FOREST FIRE DETECTION (CO-2)

- **PURPOSE**
  To detect forest fires in remote regions, maintain surveillance of hot spots.

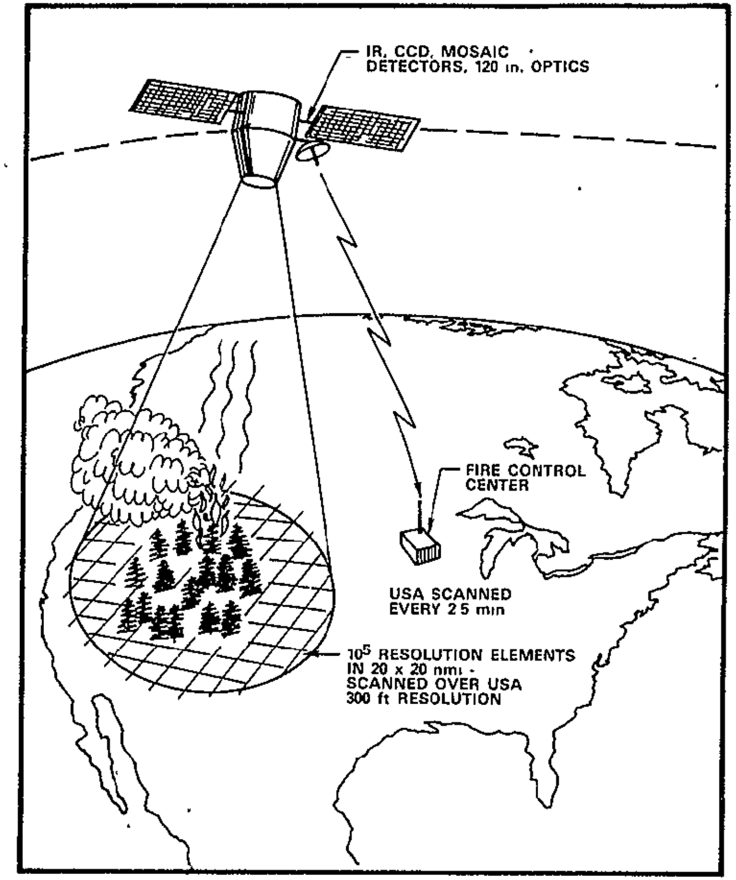
- **RATIONALE**
  Forest damage can be minimized by early detection of fires, and early firefighting.

- **CONCEPT DESCRIPTION**
  Satellite with short and long wave infrared sensors detects fires at an early stage - transmits data to control center.

- **CHARACTERISTICS**

• WEIGHT	25,000 lb
• SIZE	15 x 60 ft
• RAW POWER	2 kW
• ORBIT	Synch. Equat.
• CONSTELLATION SIZE	1
• LIFE/SERVICING PERIOD	10/3 Years
• TIME FRAME	1990
• IOC COST	230 M

- **PERFORMANCE**
  Detects fires as small as 10 x 10 ft. Location accuracy <300 ft. Resolution = 300 ft - U. S. coverage every 2 1/2 minutes.



- **BUILDING BLOCK REQUIREMENTS**

• TRANSPORTATION	Shuttle and large tug
• ON-ORBIT OPERATIONS	Automated Servicing Unit; Assemble in Orbit
• SUBSYSTEMS	Attitude control; sensor
• TECHNOLOGY	Large optical mirror; LSI data processor
• OTHER	None

CO-6 - U.N. Truce Observation Satellite (U)

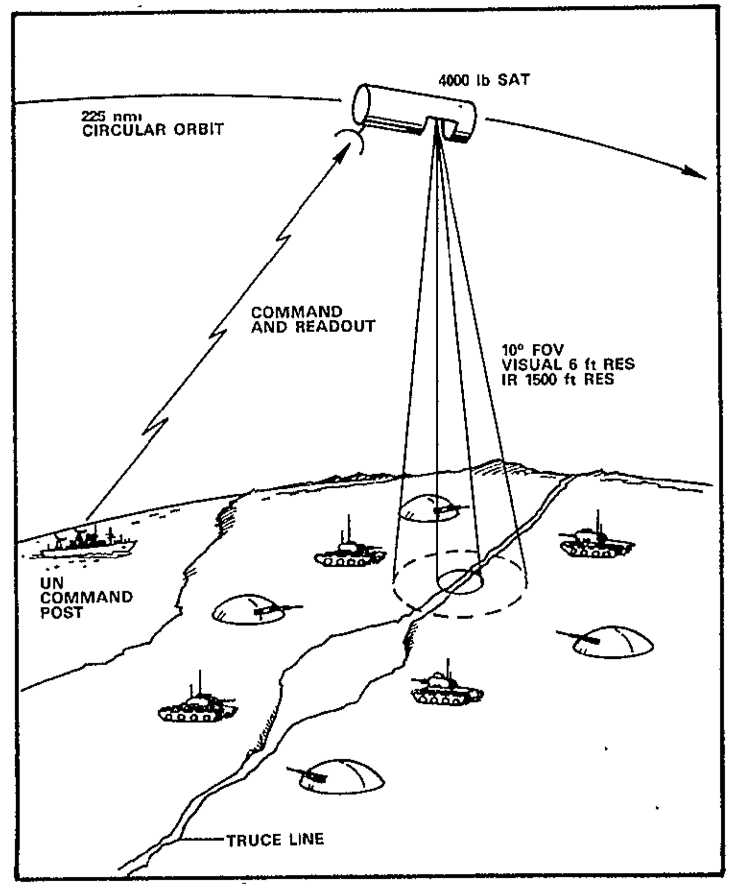
The intent of this initiative is to furnish to the United Nations truce teams the ability to monitor the order-of-battle of belligerents, and disposition of forces along truce lines, so that compliance with U.N. resolutions may properly be enforced by U.N. peace-keeping forces, once they have been assigned those functions. The read-out of optical and infrared sensors would be made direct to the local U.N. command post, whether it were fixed or mobile. The satellite is very similar to the near-term battlefield surveillance satellite mentioned in initiative MO-13. It is conceivable that the satellite would be funded by the U.N., although it is more likely that a function of a similar U.S. satellite could be made available by the U.S. to the U.N. on a time-shared basis for peace-keeping purposes.

U. N. TRUCE OBSERVATION SATELLITE (CO-6) (U)

- **PURPOSE**
  Aid U. N. teams to monitor truce agreements, particularly border zones, and weapon system dispositions such as missile launchers.
- **RATIONALE**
  U. N. will have responsibility for truce monitoring, but will be denied on-site capability in some cases. Space systems are free from local control or interference.
- **CONCEPT DESCRIPTION**
  Several low altitude satellites with visible light optics for daytime monitoring and infrared optics for night-time operation.
- **CHARACTERISTICS**

• WEIGHT	4,000 lb
• SIZE	15 x 40 ft
• RAW POWER	3 kW
• ORBIT	225 nmi polar
• CONSTELLATION SIZE	1
• LIFE/SERVICING PERIOD	10/3 Years
• TIME FRAME	1990
• IOC COST	190 M

- **PERFORMANCE**
  Ground resolution, 10 inches. (Visible) 30 ft, IR. Location accuracy, 300 ft.



- **BUILDING BLOCK REQUIREMENTS**

• TRANSPORTATION	Shuttle
• ON-ORBIT OPERATIONS	Shuttle attached manipulator
• SUBSYSTEMS	Sensor; processor
• TECHNOLOGY	Large optical mirror; LSI data processor; data link
• OTHER	None

CO-7 - Nuclear Fuel Location System (U)

The intent of this initiative is to provide a means for location and continuous tracking of all nuclear reactor fuel elements in existence in the United States, in order to minimize the possibility of hijacking and subsequent political terrorism or nuclear blackmail, which is expected to become a bad problem in the next 25 years. While this initiative will not prevent hijacking, it will make known the exact time and location of hijacking, diversion, or fuel melt-down of each nuclear reactor fuel rod (or other nuclear materials) in real time from space, so that forces can be dispatched to recover the material. The current initiative represents one innovative solution to that problem, in which an RF signal is caused to be emitted from each and every nuclear fuel element rod from manufacture until official reprocessing. All rods would be manufactured with such a signal generator included inside their cases, and old rods retrofitted. Reactors, domes, upper surfaces of trucks and depots would have to be constructed in such a way as to allow the proper frequency of RF signals to leak through into space, or appropriate transponders included. The signals would be received by a system of satellites, and location of the rods determined by time difference of arrival of the uniquely coded signals.

A signal generator in a fuel rod would have to be so constructed as to resist the high temperatures and high radiation inherent in its operation, and also operate while being transported in a truck or stored in a depot. Vacuum tube sources such as Klystrons can probably be made to operate under these conditions, and vacuum tube code generators of a subminiaturized variety could modulate the RF source. Energy for the Klystron could be supplied by a high voltage miniature thermal pile operated by the heat of the reactor when the rod is in the reactor, and by a small isotope heat source when in transit. The entire generator could be encased together with the nuclear fuel in a case so constructed as to signal penetration attempts by modulating the Klystron.

While none of the technical or political problems are easy there appear to be no fundamental reasons why they could not be solved, and the ability to monitor the position and state of health of each and every nuclear rod in the country (or for that matter in the world with proper satellite deployment), could aid in prevention of hijacking or recovery of fuel elements. This initiative is an example of the role which space could play toward solution of difficult but important National problems.

NUCLEAR FUEL LOCATION SYSTEM (CO-7) (U)

- **PURPOSE**

  To detect and locate all nuclear reactor fuel elements in real time.

- **RATIONALE**

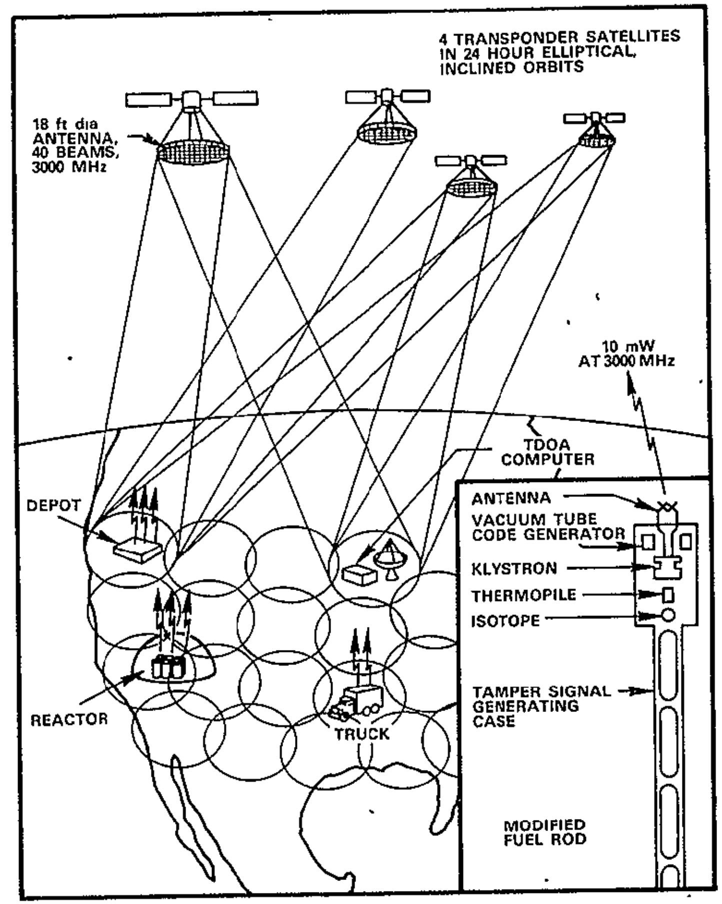
  Real-time monitoring of location of nuclear material needed to prevent proliferation of weapons and nuclear blackmail.

- **CONCEPT DESCRIPTION**

  Each fuel rod is constructed so it contains a microwave generator in a tamper-resistant case. The uniquely coded signals are transponded by 4 satellites and the position computed by time-difference-of-arrival on the ground.

- **CHARACTERISTICS**

• WEIGHT	2,000 lb
• SIZE	18 x 10 ft
• RAW POWER	300 W
• ORBIT	Synch. Ellipt./Incl.
• CONSTELLATION SIZE	4
• LIFE/SERVICING PERIOD	5 Years
• TIME FRAME	1985
• IOC COST	560 M



- **PERFORMANCE**

  Each rod identified, and located to ± 100 ft every 30 seconds, whether in a reactor, in transit, or in storage; 10,000 rods tracked simultaneously.

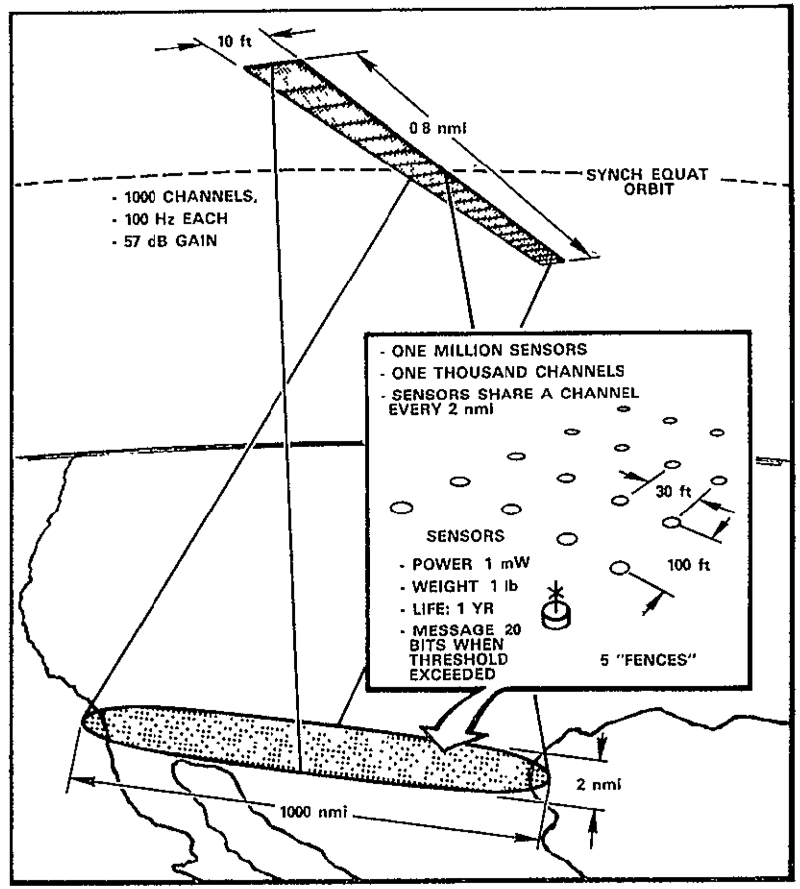
- **BUILDING BLOCK REQUIREMENTS**

• TRANSPORTATION	Shuttle and Tug
• ON-ORBIT OPERATIONS	Automated service unit
• SUBSYSTEMS	Antenna, transponder
• TECHNOLOGY	Multibeam antenna - multichannel transponder
• OTHER	LSI ground multichannel cross-correlator receivers; high temperature and high radiation resistant vacuum tube transmitter and code generator; thermopile electrical generator; tamper alarm.

CO-8 - Border Surveillance System (U)

The intent of this initiative is to monitor the signals from a number of intrusion sensors intended to signal crossing of a particular boundary. It is an example of the application of large space arrays for the detection of extremely weak and numerous sources on the surface. The figure shows an example of the Mexican border, although applications are equally valid surrounding government buildings, military bases, commercial or private property, etc. In this application, the sensors must be small and require very little power, in order to operate for long periods of time without requiring battery recharging or replacement. A typical application is shown of seismic sensors having under-surface microphones and a transmitted power of only one miliwatt, with a weight of one pound and a life exceeding ten years without battery recharging. The sensors are sown by vehicle from the air in a number of fences. Footsteps or vehicle rumblings are picked up by the sensors, transmitted, received by the space antenna, and relayed to the ground command post. Troops or helicopters could be dispatched to areas where correlation of the sensor outputs indicated penetration by people or by vehicles. In this case, an RF receiver array almost one mile long is required to obtain the aperture required to receive the signals from one million sensors, each with only one miliwatt power, in real time. Though the antenna is large, it need not be heavy. Subunits would be stationkept and the RF phasefront alignment assured by measurement and control from a master stationkept subsatellite.

BORDER SURVEILLANCE SYSTEM (CO-8)(U)



- **PURPOSE**

  To detect overt or covert attempts at crossing a border.

- **RATIONALE**

  Flow of illegal aliens and drug traffickers is a major problem. Detection is difficult along long, unpatrolled borders.

- **CONCEPT DESCRIPTION**

  Very many, very small seismic sensors are read out by a satellite with very large antenna. Penetration causes vibrations which are picked up and correlated at central site.

- **CHARACTERISTICS**

• WEIGHT	3,400 lb
• SIZE	5000 ft x 10 ft
• RAW POWER	12 kW
• ORBIT	Synch: Equat.
• CONSTELLATION SIZE	1
• LIFE/SERVICING PERIOD	10/3 Years
• TIME FRAME	1990
• IOC COST	170 M

- **PERFORMANCE**

  Virtually all moving objects detected. False alarms sorted by correlation between sensors and fences. Sensor life >10 years at 1 penetration attempt per sensor per month.

- **BUILDING BLOCK REQUIREMENTS**

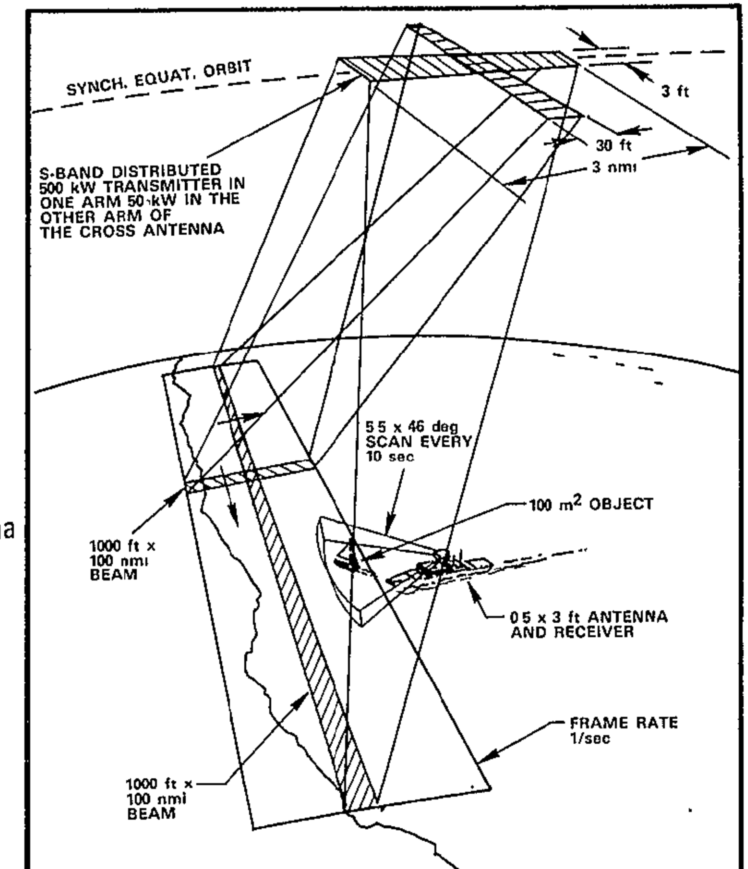
• TRANSPORTATION	Shuttle and tug
• ON-ORBIT OPERATIONS	Automated Servicing Unit
• SUBSYSTEMS	Structure; attitude control; antenna
• TECHNOLOGY	Large passive microwave antenna - stationkeeping subsatellites; laser master measuring and control unit
• OTHER	Small, light, long-lived sensor units which are very cheap in mass production.

CO-9 - Coastal Passive Radar (U)

The intent of this initiative is to make radar inexpensive and widely available to pleasure craft and other surface vessels operating in the coastal areas, for the purposes of radio location and collision avoidance. In order to do this, a bistatic radar technique is envisioned using a large space array to illuminate the coastal regions with radio energy, which is reflected from objects on the surface and received by passive receivers with scanning antennas on the pleasure craft or other users. In this way, minimum spectrum congestion and minimum expense would result. The mechanization of the technique is to fan scan the coastal area with two orthogonal beams whose minimum dimensions are 1000 feet, and which scan the coastal areas around the U.S. once per second. The time delay between signals generated when the beams sweep over an obstacle and the time when they sweep over the receiver itself are readily converted by a simple clock to a distance relative between the two objects, since the beam scan speed is known. Two scan directions are used to allow 360 deg azimuth freedom for the receiver.

Relative location is accomplished by a combination of angular resolution of the receiving array and time difference of arrival of intercepts of the scanning beams. The receivers can be simple and inexpensive, and no transmitters or modulators are required aboard the pleasure craft. An unlimited number of users can simultaneously utilize the signals generated by the space illuminators. The size of the space array is given by the location accuracy desired, which in the example is 100 feet. This sets the scanning beam width at no more than 1000 feet, which in turn sets the antenna size at about three miles in synchronous equatorial orbit. This is another example of where simplicity and economy can be gained in a very large number of users at the expense of size and complexity in a spacecraft.

COASTAL PASSIVE RADAR (CO-9)(U)



- **PURPOSE**
  Inexpensive and lightweight radar for all surface vessels - navigation; collision avoidance
- **RATIONALE**
  Conventional radar too heavy, expensive, and interferrence prone. Pleasure craft usually denied radar benefits.
- **CONCEPT DESCRIPTION**
  Use space illuminator of seacoasts with scanning microwave beams. Scanning receiving antennas on boats obtain range and angle data.
- **CHARACTERISTICS**
  - **WEIGHT** 110,000 lb
  - **SIZE** 10 nmi crossed antenna
  - **RAW POWER** 2 MN.
  - **ORBIT** Synch. Equat.
  - **CONSTELLATION SIZE** 3
  - **LIFE/SERVICING PERIOD** 10/3 Years
  - **TIME FRAME** 1995
  - **IOC COST** 1.1 B
- **PERFORMANCE**
  Relative location of all objects > 100 m^2 to within 100 ft in range and 300 ft in angle in 50^0 sector. 3 x 0.5 ft antenna in vessel.
- **BUILDING BLOCK REQUIREMENTS**
  - **TRANSPORTATION** Shuttle and large tug and large SEPS
  - **ON-ORBIT OPERATIONS** Automated Servicing Unit; Assemble in Orbit
  - **SUBSYSTEMS** Structures; attitude control; antenna
  - **TECHNOLOGY** Large adaptive microwave antenna; laser master measuring and control unit
  - **OTHER** None

CO-10 - Astronomical Telescope (U)

The intent of this initiative is to provide for an optical astronomical telescope of unprecedented resolution by mechanizing a very large array of reflectors in orbit. The technique of stationkept multiple mirrors forming a thinned crossed array with total arm length of 240 meters is utilized in this initiative, with the mirrors individually and adaptively phase controlled by command from a central stationkept focal plane unit for constructive interference at the focal plane. The resolution of the crossed array is 2.5×10^{9} radians. The use of a pair of such telescopes 100 km apart results in optical resolution as small as 10^{-11} radians. Further use of a pair of telescopes located on opposite sides of the orbit might attain resolution even smaller. Unprecedented capability could be obtained from the use of such adaptively controlled stationkept optical thinned arrays.

ASTRONOMICAL TELESCOPE (CO-10) (U)

- **PURPOSE**
  To extend knowledge of universe by examination of most distant objects.

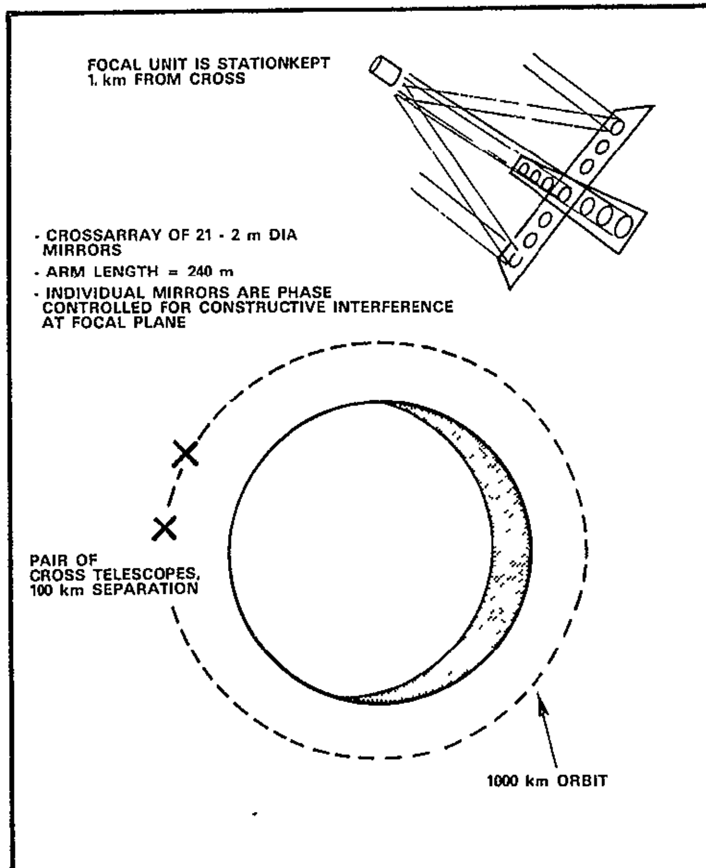
- **RATIONALE**
  Largest earth telescopes have insufficient resolution. Need even more than LST will provide.

- **CONCEPT DESCRIPTION**
  A cross-array of visible light and 100 μm mirrors and an appropriate plane can have an angular resolution of 2.5×10^{-9} radians. An orbital pair of crosses as interferometer will have resolution of 10^{-11} radians.

- **CHARACTERISTICS**

• WEIGHT	43,200 lb
• SIZE	800 ft cross
• RAW POWER	10 kW
• ORBIT	300 nmi circular
• CONSTELLATION SIZE	2 - 100 km apart
• LIFE/SERVICING PERIOD	10/1 Year
• TIME FRAME	2000
• IOC COST	690 M

- **PERFORMANCE**
  Direct parallax measurements to 6500 light years with one cross.



- **BUILDING BLOCK REQUIREMENTS**

• TRANSPORTATION	Shuttle
• ON-ORBIT OPERATIONS	Automated service unit, manned assembly
• SUBSYSTEMS	Mirrors, stationkeeping, structure, sensor
• TECHNOLOGY	Adaptive focal plane, mirrors, stationkeeping sensors
• OTHER	

CO-11 - Atmospheric Temperature Profile Sounder (U)

The intent of this initiative is to measure the temperature of the atmosphere directly as a function of its height. In this application a space laser is used in a short pulse mode to illuminate a cross-section of the atmosphere, and vibrationally excite CO_2 or H_2O in its path. The subsequent rotational transitions of these species radiate millimeter waves which are picked up and collected by a millimeter wave collecting antenna of medium size in the satellite. By proper range gating, the altitude of origination of the signal can be selected with a resolution of 100 feet by 300 feet. Measuring the ratio of the amplitude of several rotational transitions may provide an indication of the temperature of the gas at the altitude selected by the range gate, thus allowing the temperature profiles of the atmosphere to be measured directly.

ATMOSPHERIC TEMPERATURE PROFILE SOUNDER (CO-11) (U)

- **PURPOSE**
  To measure actual profiles of temperature in the atmosphere.

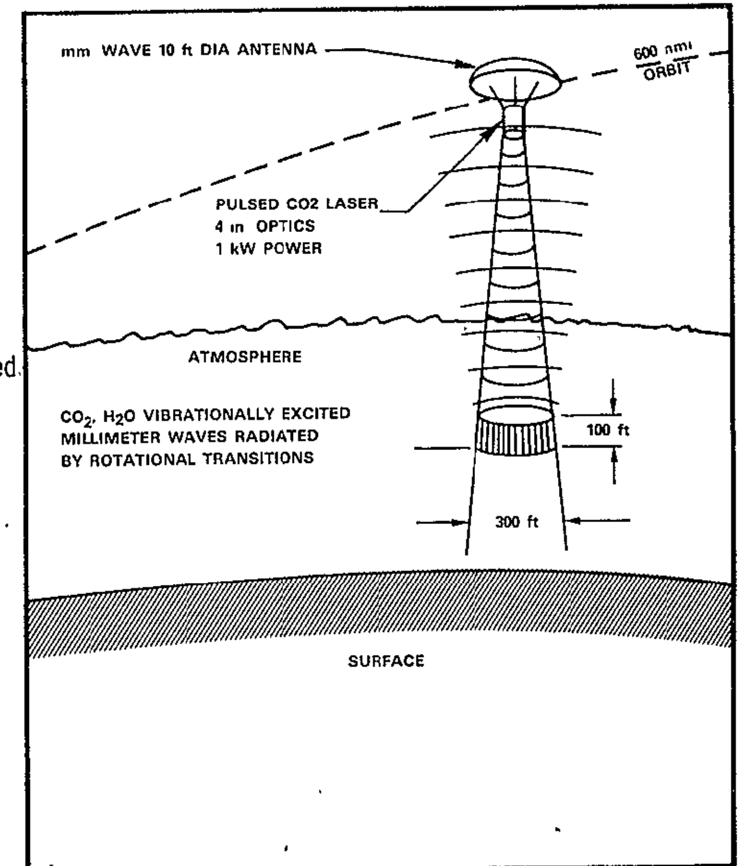
- **RATIONALE**
  Weather prediction requires knowledge of temperature profiles, as well as other phenomena.

- **CONCEPT DESCRIPTION**
  Pulsed laser vibrationally excites CO_2 or H_2O molecules. subsequent rotational transitions in the millimeter wave spectrum show temperature dependence which is measured by ratio of energy in several lines.

- **CHARACTERISTICS**

• WEIGHT	4,100 lb
• SIZE	10 ft dia antenna
• RAW POWER	5 kW
• ORBIT	600 nmi polar
• CONSTELLATION SIZE	4
• LIFE/SERVICING PERIOD	10/3 Years
• TIME FRAME	1990
• IOC COST	340 M

- **PERFORMANCE**
  Entire atmosphere measured, with resolution of 300 ft horizontally and 100 ft vertically, every four hours.



- **BUILDING BLOCK REQUIREMENTS**

• TRANSPORTATION	Shuttle and SEPS
• ON-ORBIT OPERATIONS	Automated service unit
• SUBSYSTEMS	Antenna, laser, attitude control
• TECHNOLOGY	Laser, power dissipation, antenna, pointing
• OTHER	Phenomenology of rotation/vibration measurements

CC-1 - Global Search + Rescue Locator (U)

The intent of this initiative is to locate small, lightweight emergency transmitters by a system of high altitude comsats, and to allow the use of small, inexpensive, lightweight emergency transmitters. The satellites transpond the signals from the emergency transmitter and the location is computed by time difference of arrival on the ground site. The emergency transmitters can be very tiny, weighing a pound or two and having a continuous life for at least a month self-contained. Each transmitter would have stored a unique code out of a catalog of 100 or more codes stored in the ground cross-correlation receivers. The transponders have 100 frequency-multiplexed channels.

Emergency transmitters of this size are small enough to be carried by everyone venturing away from popular areas, such as hikers, pleasure boats, or cars traveling between cities. A much more modest system for use only by official vehicles or aircraft could use a single channel transponder and time-share a few correlator receivers.

GLOBAL SEARCH + RESCUE LOCATOR (CC-1)(U)

- **PURPOSE**
  To locate emergency transmitters world-wide; to allow small, lightweight transmitters.

- **RATIONALE**
  Search for rescue is expensive and not always successful.

- **CONCEPT DESCRIPTION**
  Coded, small transmitter in emergency package carried by traveling boats, aircraft. Signals received and transponded by satellites, and location computed by TDOA techniques.

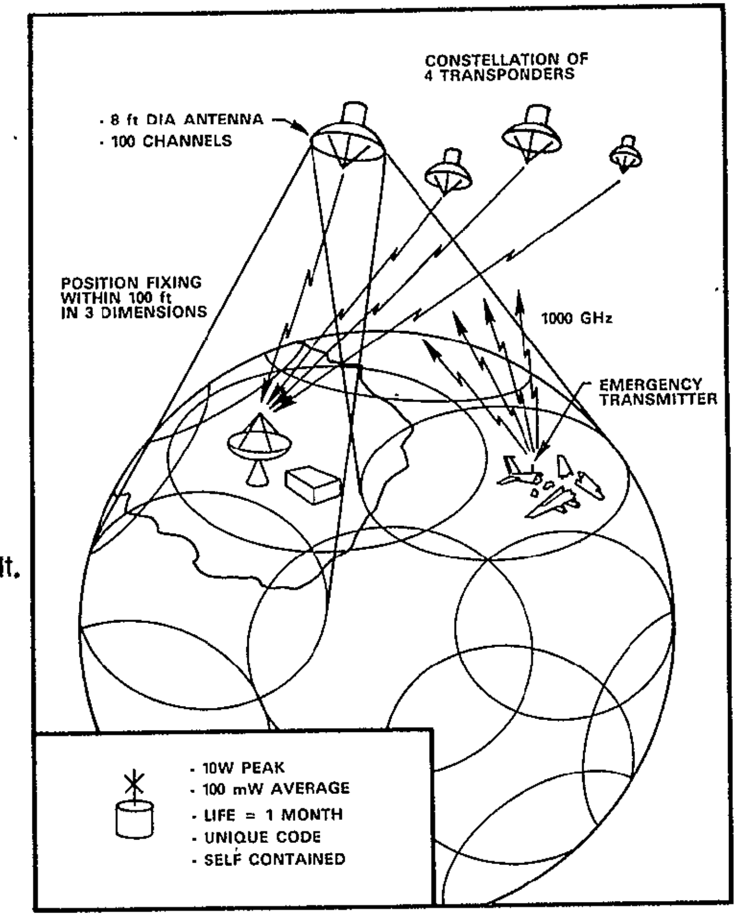
- **CHARACTERISTICS**

• WEIGHT	2,000 lb
• SIZE	5 x 7 ft
• RAW POWER	500 W
• ORBIT	Near-Synch., or Med. Alt.
• CONSTELLATION SIZE	20
• LIFE/SERVICING PERIOD	10/3 Years
• TIME FRAME	1980
• IOC COST	700 M

- **PERFORMANCE**
  Location of emergency transmitters to ± 10 ft in 3 coordinates. Transmitter weight ≈ 1 lb, life > 1 month continuous operation.

- **BUILDING BLOCK REQUIREMENTS**

• TRANSPORTATION	Shuttle and tug
• ON-ORBIT OPERATIONS	Automated Servicing Unit
• SUBSYSTEMS	No unusual requirements
• TECHNOLOGY	No unusual requirements
• OTHER	None



CC-2 - Urban-Police Wrist Radio (U)

In this application, large numbers of very tiny ground transmitters and receivers are serviced by a large multibeam antenna for enabling completely mobile personal communications to a large number of simultaneous users. This particular initiative addresses the urban and police command and control problem. Each policeman could be outfitted with a wristwatch radio of low radiated power and battery drain, using LSI microelectronic technology, and its battery could be recharged at the police station daily while the policeman is not on duty. The radio would have a two-way voice capability, and with the LSI, would have a digital vocoder and anti-jam capability as well. Such radios could be mass-produced, be very inexpensive, and wholly self-contained.

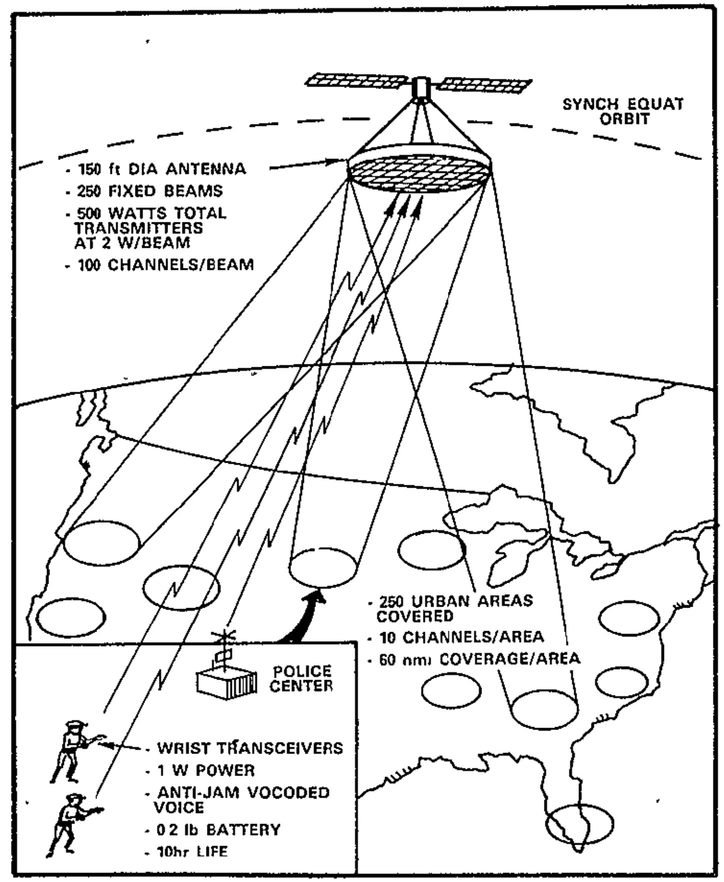
The space system component needs a large receiving aperture, multiple beam capability, and on-board multiple-access processing to service the wristwatch radios. Furthermore, the provision of large space antennas obviates the need for high transmitter power. Since the cost of the system will be dominated by the user equipment, such complex satellites may result in overall minimum costs.

URBAN/POLICE WRIST RADIO (CC-2)(U)

- **PURPOSE**
  To give real-time, secure, anti-jam, high coverage, wide area communications to each policeman.
- **RATIONALE**
  Police need help in doing their job. Spectrum congested. Jamming/eavesdropping will become routine.
- **CONCEPT DESCRIPTION**
  Wrist 2-way transceiver and channelized Comsat give instant 2-way communications to patrolmen. Multibeam antenna, anti-jam processing, and pseudo-random coding make jamming very hard.
- **CHARACTERISTICS**

• WEIGHT	8,100 lb
• SIZE	150 ft dia. antenna
• RAW POWER	1.5 kW
• ORBIT	Synch. Equat.
• CONSTELLATION SIZE	1
• LIFE/SERVICING PERIOD	10/3 Years
• TIME FRAME	1990
• IOC COST	270 M

- **PERFORMANCE**
  10 clear channels/city, 250 cities simultaneously.
  30 db anti-jam and pseudo-random codes.
  0.2 lb battery for 10 hr life at 30% duty.



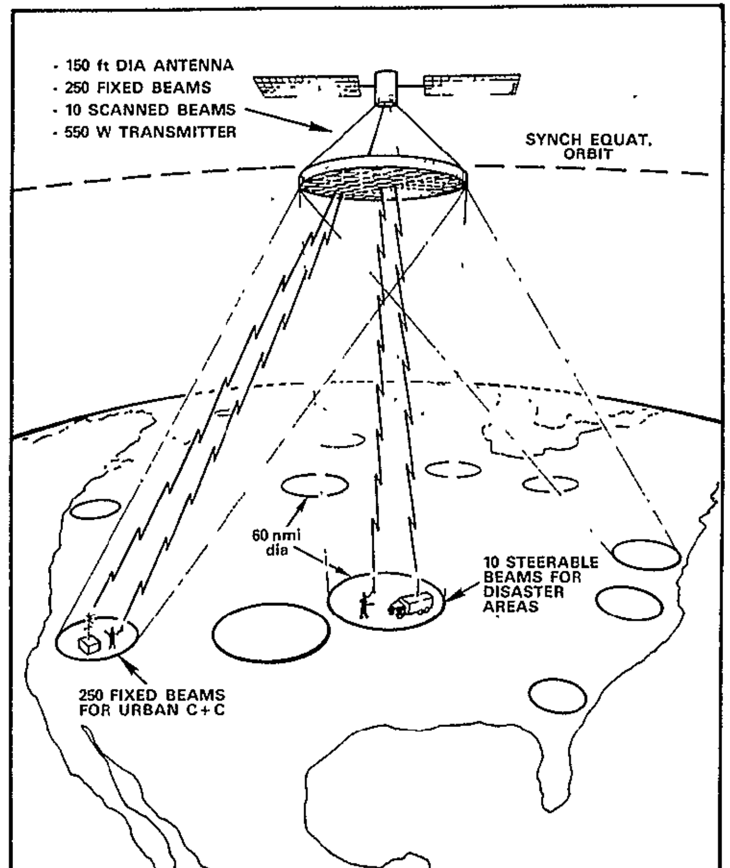
- **BUILDING BLOCK REQUIREMENTS**

• TRANSPORTATION	Shuttle and tug and SEPS
• ON-ORBIT OPERATIONS	Automated Servicing Unit
• SUBSYSTEMS	Attitude control; antenna; processor
• TECHNOLOGY	Large multibeam antenna; multi-channel transponder; LSI processor; multi-access techniques
• OTHER	Wrist transceiver, LSI technology

CC-3 - Disaster Control Satellite (U)

This application is similar to that of CC-2 (Urban-Police Wrist Radio) except that a number of steerable beams are added to the satellite to provide communications, command, and control to the host of personnel associated with disaster services in disaster areas. Ten simultaneous disaster areas are covered in the United States, with ten channels of secure, anti-jam coded voice communications per area.

DISASTER CONTROL SATELLITE (CC-3)(U)



- **PURPOSE**

  To provide communications, command, and control to disaster area emergency personnel.

- **RATIONALE**

  Lack of communications hampers quick and effective handling of emergencies.

- **CONCEPT DESCRIPTION**

  Add 10 pointable beams to the urban/police (CC-3) system, point to disaster areas.

- **CHARACTERISTICS**

• WEIGHT	8,100 lb
• SIZE	150 ft dia. antenna
• RAW POWER	1.5 kW
• ORBIT	Synch. Equat.
• CONSTELLATION SIZE	1
• LIFE/SERVICING PERIOD	10/3 Years
• TIME FRAME	1990
• IOC COST	270 M

- **PERFORMANCE**

  Provides 10 disaster areas and 250 urban centers with 10 channels of voice communications each. Secure, anti-jam coded.

- **BUILDING BLOCK REQUIREMENTS**

• TRANSPORTATION	Shuttle and tug and SEPS
• ON-ORBIT OPERATIONS	Automated Servicing Unit
• SUBSYSTEMS	Attitude control; antenna; processor
• TECHNOLOGY	Large multibeam antenna; multi-channel transponder; LSI processor; multiple-access techniques
• OTHER	None

CC-4 - Electronic Mail Transmission (U)

The intent of this initiative is to allow the rapid and efficient transmission of mail information by electronic means from post office to post office. The concept envisions page readers in post offices reading out the written information on letters which are opened by machine, transmitting this information to facsimile printers at the receiving post office where the pages are sealed by machine and delivered by letter carrier to the home. This is an intermediate step to an ultimate system where all-electronic transmission from home to home will be made possible through comsats without going through a written phase or any post office, obtaining a hard copy or only an image at the receiver as desired.

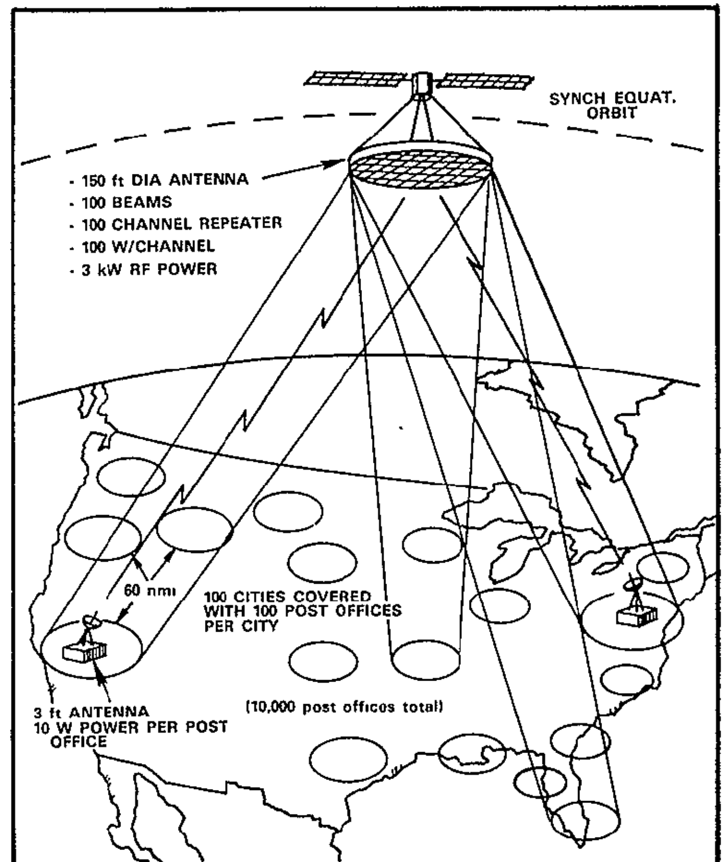
A system typical of such an application has been sized which can handle ten letter pages per second per post office, with 100 post offices per city in 100 cities simultaneously being serviced. That's a total of 100,000 pages per second, or 8.6 billion pages per day. The system envisioned consists of a large space antenna with multibeam capability which will allow the post-office transmitter and antenna to be small and inexpensive. The power required in the satellite is not large, and the antenna size makes footprints large enough that they cover most urban areas, with the post offices in the areas between the urban centers connecting to the urban areas by landline. An alternative is to use 300 beam feeds and 10 KW RF power and cover the entire USA, which is conceptually no more difficult since not every 60 nmi area throughout the country will contain 100 post offices.

ELECTRONIC MAIL TRANSMISSION (CC-4)(U)

- **PURPOSE**
  To speed up mail, and lower costs.

- **RATIONALE**
  Self evident

- **CONCEPT DESCRIPTION**
  Page readers and facsimile printers at each post office read, transmit, receive, and reproduce mail. Satellite acts as multichannel repeater.



- **CHARACTERISTICS**

• WEIGHT	8,500 lb
• SIZE	150 ft dia. antenna
• RAW POWER	10 kW
• ORBIT	Synch. Equat.
• CONSTELLATION SIZE	1
• LIFE/SERVICING PERIOD	10/3 Years
• TIME FRAME	1990
• IOC COST	280 M

- **PERFORMANCE**
  Transmits facsimile at 10 pages (8 1/2 x 11") per second per post office; 100 post offices per city, 100 cities - (10, 000 channels total).

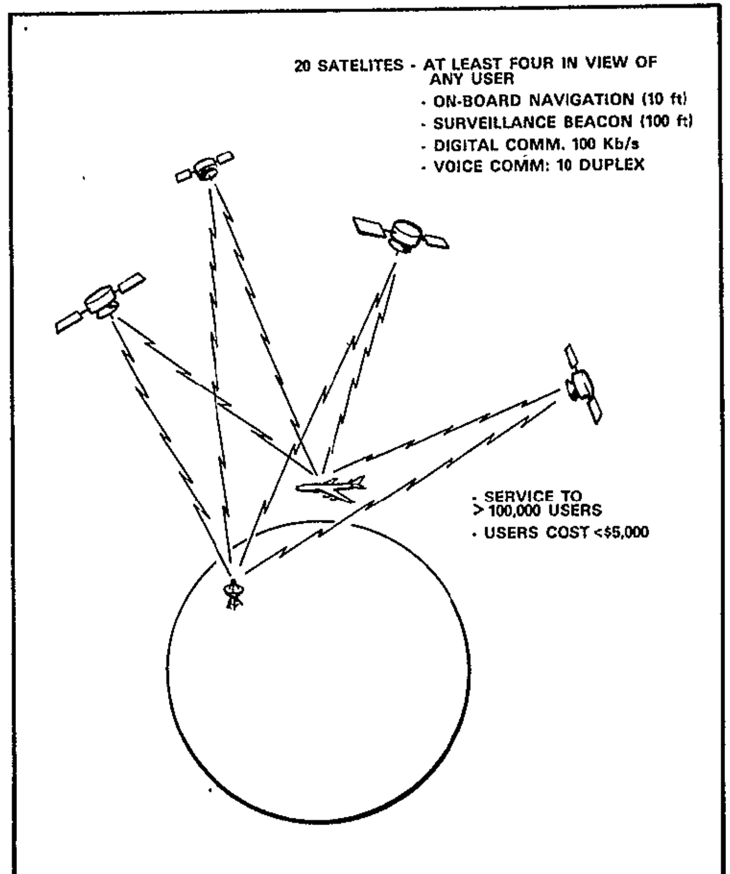
- **BUILDING BLOCK REQUIREMENTS**

• TRANSPORTATION	Shuttle and tug and SEPS
• ON-ORBIT OPERATIONS	Automated Servicing Unit
• SUBSYSTEMS	Attitude control; antenna; processor
• TECHNOLOGY	Large multibeam antenna; multi-channel transponder; LSI processor; multiple-access techniques
• OTHER	None

CC-5 - Transportation Services Satellites (U)

The intent of this initiative is to field a system of satellites similar to the DOD Global Positioning System satellites, but consisting of transponders rather than only transmitters so that position computations can be made by the central receiving and control station as well as by the mobile users. Furthermore, such transponders could relay two-way digital messages, forming the backbone of surveillance, navigation, and communication requirements for the common carrier and private transportation systems. Unique codes and sophisticated receivers are used providing a capability greatly in excess of any in existence today, which can be provided simultaneously to a multiplicity of users without interference. This is a near-term system concept.

TRANSPORTATION SERVICES SATELLITES (CC-5) (U)



- **PURPOSE**

  Simultaneously satisfy traffic control, air surveillance, navigation, position fixing, command/control for multiplicity of uses.

- **RATIONALE**

  Similar and overlapping requirements by many agencies for precision navigation enable one comprehensive system to meet all needs for all users.

- **CONCEPT DESCRIPTION**

  Comsat transponders are used, with 4 in view of user at different angles/ranges, to provide TDOA position fixing and 2-way communications.

- **CHARACTERISTICS**

• WEIGHT	1400 lb
• SIZE	6 x 8 ft
• RAW POWER	600W
• ORBIT	8000 polar
• CONSTELLATION SIZE	20
• LIFE/SERVICING PERIOD	10/3 Years
• TIME FRAME	1985
• IOC COST	620 M

- **PERFORMANCE**

  100,000 users serviced: position to 10 ft, surveillance of beacon to 100 ft, digital communications of 100 kb/sec.

- **BUILDING BLOCK REQUIREMENTS**

• TRANSPORTATION	Shuttle and tug
• ON-ORBIT OPERATIONS	Automated Servicing Unit
• SUBSYSTEMS	No unusual requirements
• TECHNOLOGY	No unusual requirements
• OTHER	None

CC-7 - Voting-Polling System (U)

Another application of large space antennas with multiple beams is for mass communication to and from personal wrist radios. This particular application envisions that every adult citizen could have a wrist radio which, in addition to furnishing the means of personal two-way communications, could have a dual function of allowing elected representatives to reach large segments of the population essentially instantaneously for the purposes of polling the population on their feelings on major issues of government or public policy. Furthermore, the capability would then exist for people to register votes directly with the government on a real-time basis in participatory democracy elections. The personal polling/voting could be mechanized as short digital messages, with the wrist radios being constructed with yes-no-and no-interest buttons, in addition to a small digital message entry/display unit.

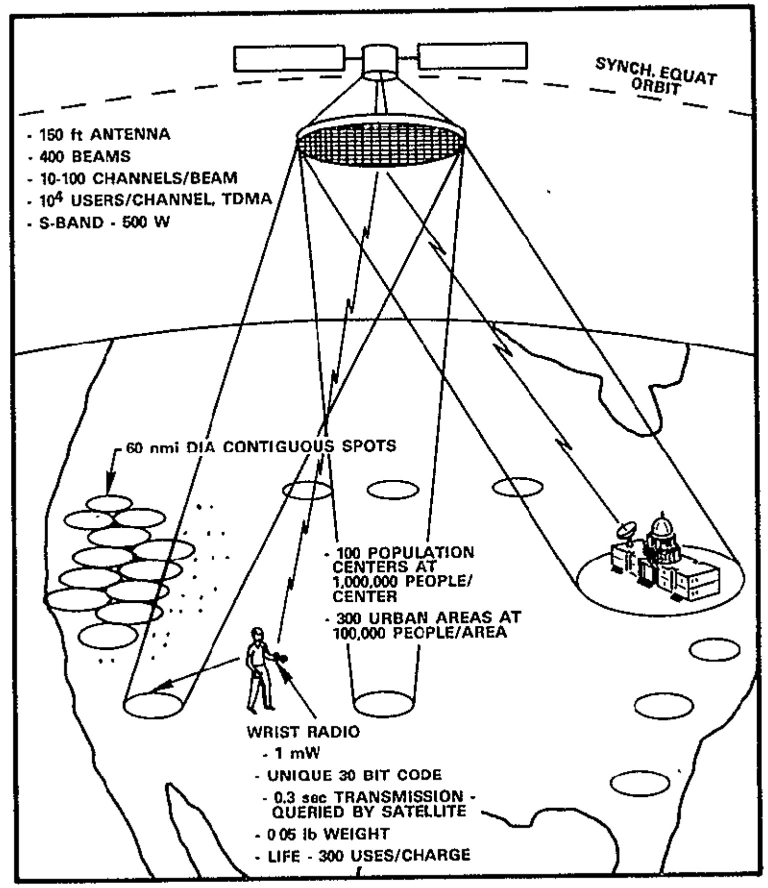
Such a voting/polling system could have the capability of reaching 100 million people in one hour throughout the USA, for truly real-time assessment of how the population feels on issues of the moment. Unique pseudo-random coding would be supplied to each wrist radio, and any four-bit message could be transmitted from the wrist radio being interrogated by the satellite system.

VOTING/POLLING SYSTEM (CC-7)(U)

- **PURPOSE**
  To provide direct access to people for voting or polling purposes.

- **RATIONALE**
  Voting and polling are time-consuming processes, and subject to many errors.

- **CONCEPT DESCRIPTION**
  Multichannel satellite queries wrist radios, and relays responses to Washington from individual voters. Pseudo-random codes authenticate votes.



- **CHARACTERISTICS**

• WEIGHT	8,100 lb
• SIZE	150 ft dia. antenna
• RAW POWER	1.5 kW
• ORBIT	Synch. Equat.
• CONSTELLATION SIZE	1
• LIFE/SERVICING PERIOD	10/3 Years
• TIME FRAME	1990
• IOC COST	270 M

- **PERFORMANCE**
  100,000,000 people polled/vote in 1 hr.
  Any 4 bit message relayed.

- **BUILDING BLOCK REQUIREMENTS**

• TRANSPORTATION	Shuttle and tug and SEPS
• ON-ORBIT OPERATIONS	Automated Servicing Unit
• SUBSYSTEMS	Attitude control; antenna; processor
• TECHNOLOGY	Large multibeam antenna; multi-channel transponder; LSI processor; multiple-access techniques
• OTHER	LSI wrist transceiver

CC-8 - National Information Services System (U)

The intent of this initiative is to provide international networks with a capability to serve many users having small antennas and small power for data or voice communications with remote areas. A typical user terminal will have one watt of transmitter power and a three-foot antenna, and handle either 100 users at one megabit per second each or 10,000 users at ten kilobits each. The major components of the satellite are a 150-foot diameter antenna with 100 independent beams and a 100-channel repeater. With such an initiative, the benefits of common-carrier communications could be brought to much smaller and less concentrated users than with the current Intelsat network.

NATIONAL INFORMATION SERVICES SYSTEM (CC-8) (U)

- **PURPOSE**

  To provide Intelsat network with adjunct capability to serve small-antenna users.

- **RATIONALE**

  Intelsat requires very large antennas and few entry points - not suited for disadvantaged users.

- **CONCEPT DESCRIPTION**

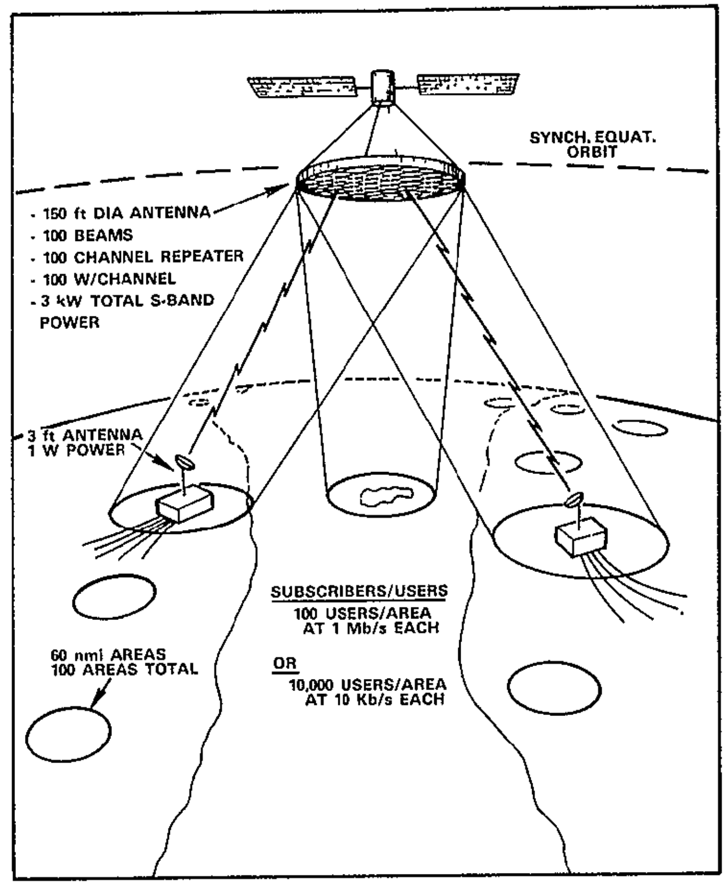
  Large multibeam antenna satellites link facsimile voice and teletype terminals with low power and small antennas. Satellite is a multichannel repeater.

- **CHARACTERISTICS**

• WEIGHT	8,500 lb
• SIZE	150 ft dia antenna
• RAW POWER	10 kW
• ORBIT	Synch. Equat.
• CONSTELLATION SIZE	4
• LIFE/SERVICING PERIOD	10/3 Years
• TIME FRAME	1990
• IOC COST	420 M

- **PERFORMANCE**

  40,000 to 4 million channels in 400 areas serviced world-wide, with 1 watt transmitter and 3 ft antenna at user terminal.



- **BUILDING BLOCK REQUIREMENTS**

• TRANSPORTATION	Shuttle and tug and SEPS
• ON-ORBIT OPERATIONS	Automated Servicing Unit
• SUBSYSTEMS	Attitude control; antenna; processor
• TECHNOLOGY	Large multibeam antenna; multi-channel transponder; LSI processor; multiple-access techniques
• OTHER	None

CC-9 - Personal Communications (U)

The intent of this initiative is to extend two-way telephone service to individuals wherever they are, by outfitting interested individuals with self-contained wristwatch radio terminals. People can then be in touch with each other, or with fixed installations, through the satellite network wherever they are. Since the wrist terminal should have at least one day continuous operating life prior to recharging the batteries, the transmitter power must be very small. In the example here of the initiative, it is 25 mW. The multibeam antenna satellite covers a number of urban concentration areas and allows one million people in each of 25 cities to communicate through the central switching stations, providing 25, 000 simultaneous channels of normal voice, and servicing as many as 25 million people. The satellite is fitted with LSI processors for voice recognition of the address code in lieu of a dial address code, with automatic switching and message routing being shared between ground and satellite equipments. This initiative is similar to many others in the catalogue which are intended to satisfy a need for inexpensive and highly portable personal communication terminals, achievable with satellite size and complexity.

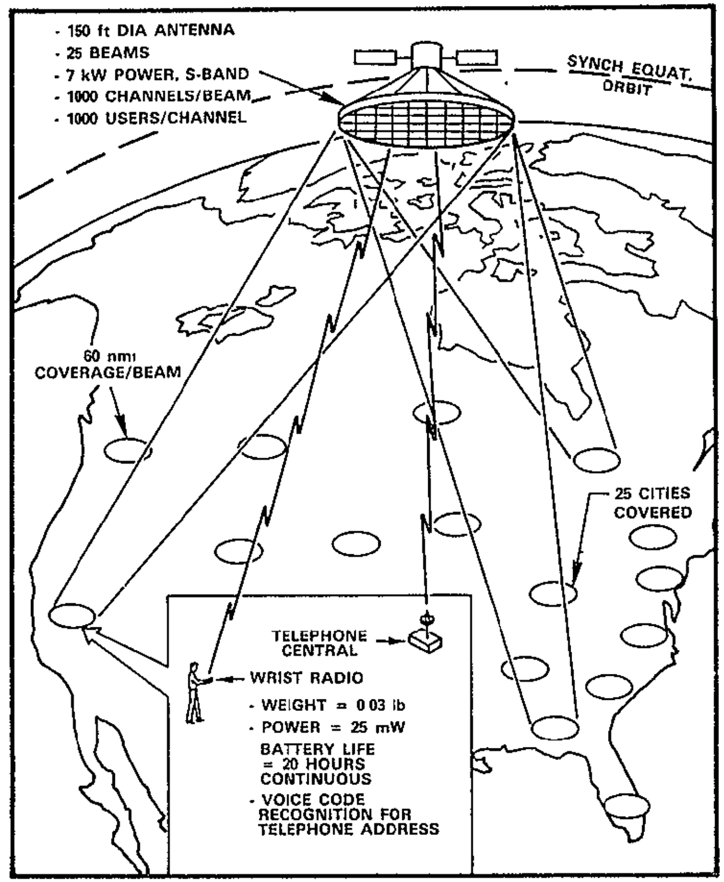
- **PURPOSE**
  To allow citizens to communicate through exchanges by voice, from anywhere.

- **RATIONALE**
  Mobile telephones are desirable, but should be wrist worn. Many mobile users want communications.

- **CONCEPT DESCRIPTION**
  Multichannel repeater and wrist transmitter-receivers connect people anywhere. Voice code recognition address (phone-number).

- **CHARACTERISTICS**

• WEIGHT	9,200 lb
• SIZE	150 ft dia. antenna
• RAW POWER	21 kW
• ORBIT	Synch. Equat.
• CONSTELLATION SIZE	1
• LIFE/SERVICING PERIOD	10/3 Years
• TIME FRAME	1990
• IOC COST	320 M



- **PERFORMANCE**
  1,000,000 people in each of 25 cities can communicate, 25,000 simultaneously, using normal voice.

- **BUILDING BLOCK REQUIREMENTS**

• TRANSPORTATION	Shuttle and large tug
• ON-ORBIT OPERATIONS	Automated Servicing Unit
• SUBSYSTEMS	Attitude control; antenna; processor
• TECHNOLOGY	Large multibeam antenna; multi-channel transponder; LSI processor, multiple-access techniques
• OTHER	Wrist transceiver, LSI technology

CC-10 - Diplomatic/UN Hot Line (U)

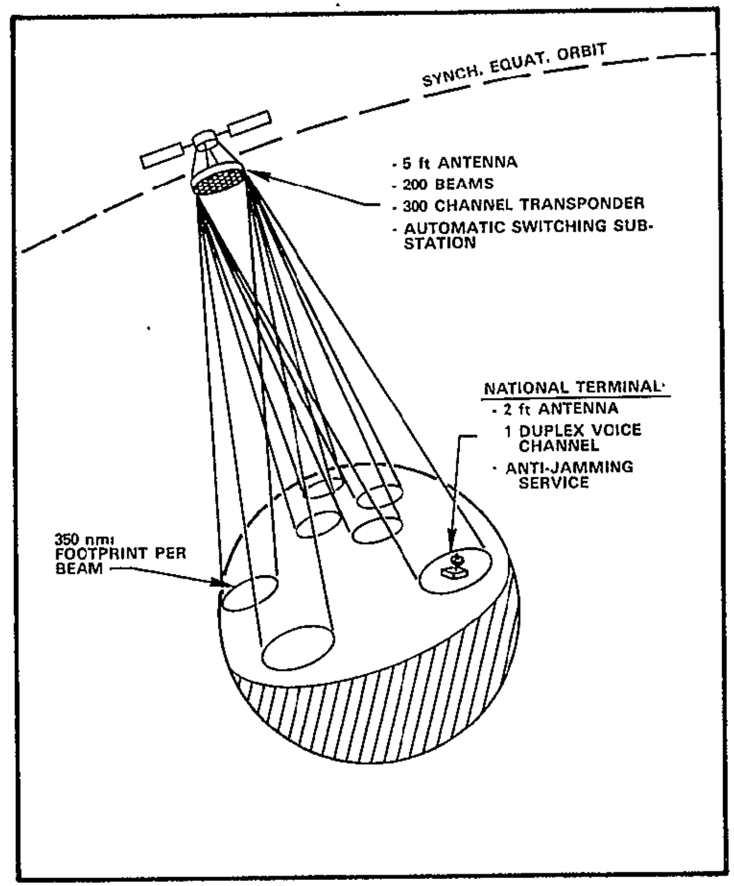
The intent of this initiative is to provide hot line communications between heads of state of all major nations of the world; to provide a medium for easing tensions, negotiating conditions, and reducing the danger of escalation of minor conflicts into major ones. The dedicated nature of the satellite and its mutual need by all nations makes it an unlikely target. The satellite is large enough and powerful enough that a two-foot antenna terminal is sufficient to set up a duplex voice channel with anti-jam coding, which is automatically switched in the satellite to whichever country addressee the call initiator specifies. Thus any country can be in touch with any other country at will without subject to the whims of any other country, and the automatic switching equipment is satellite borne and pre-programmed, insuring fairness of access to all and not subject to capture by any party who may be interested in upsetting communications. The satellite antenna is state-of-the-art, although the automatic switching substation requires development of an appropriate LSI processor and multiple access techniques.

- **PURPOSE**
  To provide rapid, reliable, secure communications between heads of state and embassies.
- **RATIONALE**
  Good, rapid communications needed to reduce dangers of escalation in international situations.
- **CONCEPT DESCRIPTION**
  Multibeam antenna Comsat crosslinks any or all terminals, one per country. Satellite processing is autonomous and not subject to capture.
- **CHARACTERISTICS**

• WEIGHT	3,000 lb
• SIZE	5'x 15 ft
• RAW POWER	1 kW
• ORBIT	Synch Equat.
• CONSTELLATION SIZE	3
• LIFE/SERVICING PERIOD	10/3 Years
• TIME FRAME	1980
• IOC COST	230 M

- **PERFORMANCE**
  One full duplex voice channel per country, 200 countries accommodated. Automatic switching in satellite; or multiple access user-controlled.
- **BUILDING BLOCK REQUIREMENTS**

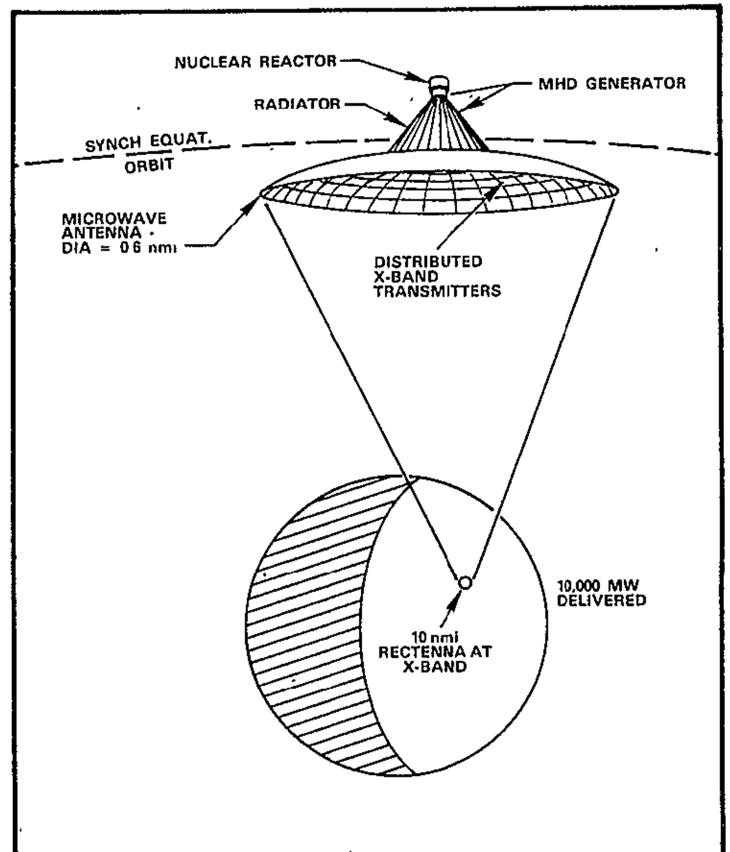
• TRANSPORTATION	Shuttle and tug
• ON-ORBIT OPERATIONS	Automated Servicing Unit
• SUBSYSTEMS	Attitude control; antenna; processor and switch
• TECHNOLOGY	Multibeam antenna; multi-channel transponder; LSI processor and automatic switch; multiple-access techniques
• OTHER	None



CS-1 - Nuclear Energy Plant in Space (U)

The intent of this initiative is to generate large scale energy in space and to transmit it to receiving antennas on the ground via microwave beams for terrestrial use. In this initiative, the generator is a nuclear reactor driving an MHD generator producing electrical power, which is then beamed from a microwave antenna with distributed transmitters to a rectenna on the ground. A breeder reactor is contemplated, with fuel breeding designed to supply reactor fuel for operation at the initial power level for at least a thousand years. No pollution is produced by this energy generation technique, and at the end of its life, all radioactive components can be disposed to deep space or retained in orbit and closely watched. The receiving device could be a "form" of thin wire dipoles and rectifiers of 5 nmi diameter suspended on poles, under which farming or industry could ready exist so that the land area is not wasted. The advantages of this form of energy generation and delivery are self-evident.

NUCLEAR ENERGY PLANT IN SPACE (CS-1) (U)



- **PURPOSE**
  To generate and deliver electrical energy without pollution or hazard.

- **RATIONALE**
  Power is needed which requires no radioactive material on earth, produces no atmospheric heating, and no resource consumption.

- **CONCEPT DESCRIPTION**
  A breeder reactor MHD power generator, microwave transmitter, and microwave antenna are used to beam energy to a ground receiver. Fuel breeding supplies fuel for at least 1000 years of operation.

- **CHARACTERISTICS**

• **WEIGHT**	81,000,000 lb
• **SIZE**	3600 ft dia
• **RAW POWER**	13,000 MW
• **ORBIT**	Synch. Equat.
• **CONSTELLATION SIZE**	1
• **LIFE/SERVICING PERIOD**	1000/3 Years
• **TIME FRAME**	2000
• **IOC COST**	15.7 B

- **PERFORMANCE**
  10,000 megawatts delivered power continuously - with sufficient fuel breeding for a life of at least 1000 years.

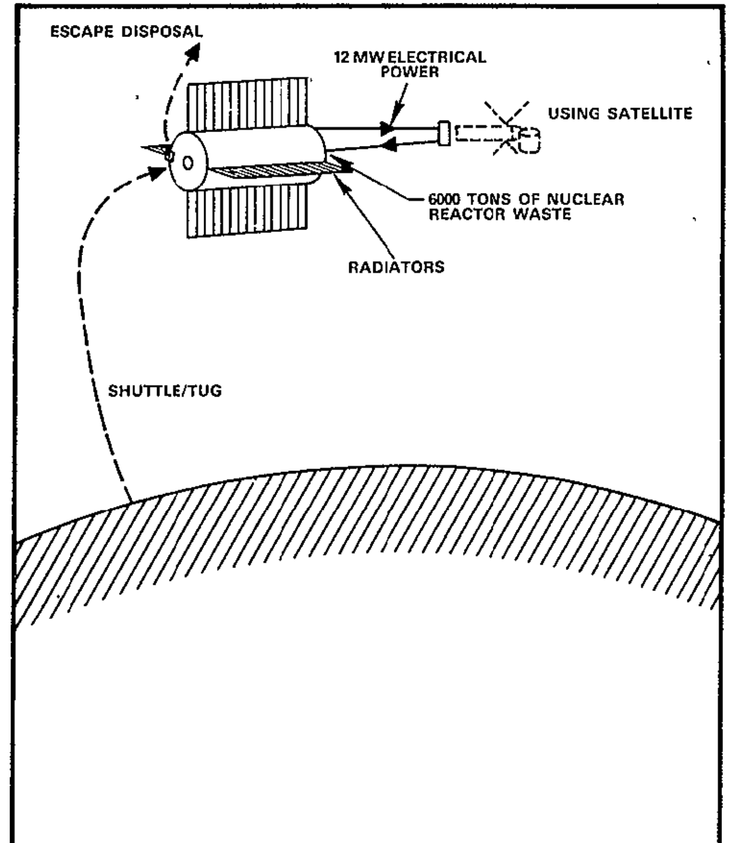
- **BUILDING BLOCK REQUIREMENTS**

• **TRANSPORTATION**	LLV and large tug and large SEPS
• **ON-ORBIT OPERATIONS**	Manned service unit; automated servicing unit; Assemble in orbit
• **SUBSYSTEMS**	Structure; attitude control; antenna; reactor; power unit
• **TECHNOLOGY**	Large active microwave antenna; large reactor; heat radiator; HHD power generator; pointing and tracking sensor
• **OTHER**	Rectenna on ground, safety

CS-2 - Energy Generation Plant (RTG) (U)

The intent of this initiative is to utilize the radioactive nuclear wastes from ground nuclear reactors for generating electrical power in orbit prior to their disposal into deep space. Six-thousand tons of nuclear reactor waste (of the intense variety with half life in the order of 30 years) is expected to be produced by the year 2000 by the world's surface nuclear reactor power plants at the current growth rate. This nuclear reactor waste could be put into orbit with minimal pre-processing and assembled into a radioisotope thermal generator which could be used to power a satellite, or to directly provide power elsewhere in space or on the ground. It is estimated that 12 MW of electrical power can be made available for 30 years, using such waste. After 30 years, when the wastes begin losing their intensity rapidly, they could be disposed into deep space, into the sun, or simply stored in orbit and watched, and another load of wastes from the earth used for renewing the generator.

ENERGY GENERATION PLANT (RTG) (CS-2) (U)



- **PURPOSE**
  To use nuclear reactor wastes for producing energy in space, before disposing in deep space.

- **RATIONALE**
  If we are going to dispose of reactor wastes in space, let's use their heat for 30 years before final disposal.

- **CONCEPT DESCRIPTION**
  A large thermoelectric plant is fueled by nuclear wastes brought in via shuttle. After 30 years, the wastes are disposed of in deep space.

- **CHARACTERISTICS**

• WEIGHT	15,000,000 lb
• SIZE	
• RAW POWER	12 MW
• ORBIT	1000 nmi
• CONSTELLATION SIZE	1
• LIFE/SERVICING PERIOD	> 25/3 Years
• TIME FRAME	2000
• IOC COST	3.5 B

- **PERFORMANCE**
  12 megawatts electrical power generated from total nuclear reactor wastes accumulated by year 2000.

- **BUILDING BLOCK REQUIREMENTS**

• TRANSPORTATION	LLV and large tug and large SEPS
• ON-ORBIT OPERATIONS	Automated Servicing Unit; Assemble In Orbit
• SUBSYSTEMS	Attitude control; thermal; power conversion
• TECHNOLOGY	Isotope; thermoelectrics; radiator; safety encapsulation/shielding
• OTHER	None

CS-3 - Energy Generation - Solar/Microwave (U)

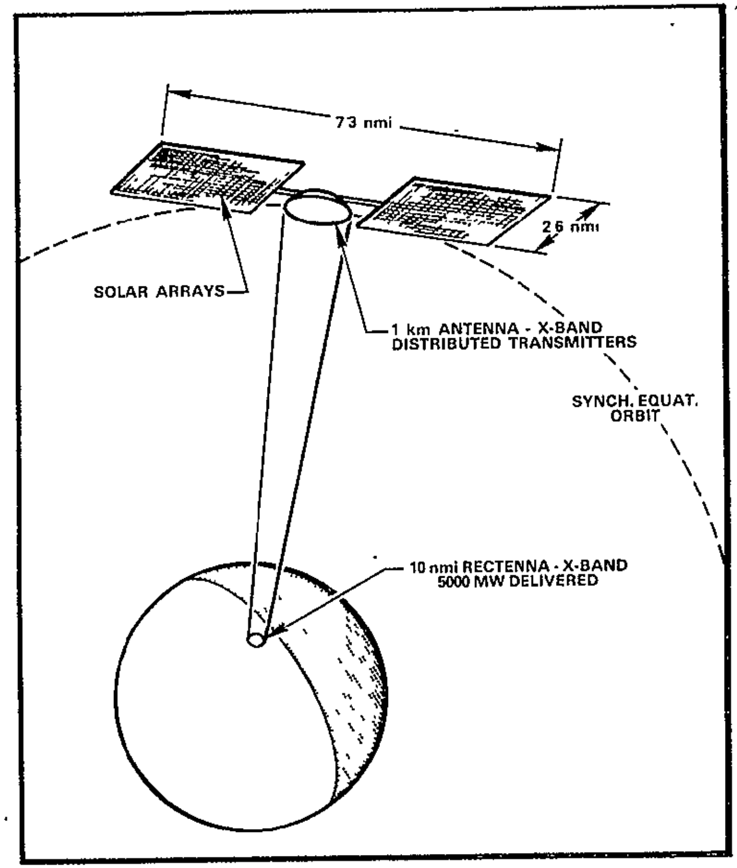
The intent of this initiative is to collect solar energy in space, convert it into microwave energy, and beam it to the earth for reception by rectenna for use in a terrestrial power plant. This initiative is identical to the Satellite Solar Power System concept studied by A. D. Little for NASA in the recent past. This energy generator has no nuclear or radioactive components, but is considerably larger than the CS-1 nuclear plant for the same power.

ENERGY GENERATION - SOLAR/MICROWAVE (CS-3) (U)

- **PURPOSE**
  To provide abundant electrical power with little pollution.

- **RATIONALE**
  More and clean energy needed.

- **CONCEPT DESCRIPTION**
  Solar energy is collected, converted to microwave energy, and transmitted to earth, where it is rectified to DC by a rectenna.



- **CHARACTERISTICS**

• WEIGHT	25,000,000 lb
• SIZE	7.3 x 2.6 nmi
• RAW POWER	10,000 MW
• ORBIT	Synch. Equat.
• CONSTELLATION SIZE	1
• LIFE/SERVICING PERIOD	> 25/3 Years
• TIME FRAME	2000
• IOC COST	11 B

- **PERFORMANCE**
  5000 megawatts supplied to 10 nmi collector, with less than 500 MW lost as heat to the environment.

- **BUILDING BLOCK REQUIREMENTS**

• TRANSPORTATION	LLV and large tug and large SEPS
• ON-ORBIT OPERATIONS	Manned Servicing Unit; Assemble in Orbit
• SUBSYSTEMS	Attitude control; structures; power antenna
• TECHNOLOGY	Large economical solar arrays; large active microwave antenna; high power tubes; feeding and cross-connects
• OTHER	Rectenna on ground

CS-4 - Nuclear Waste Disposal (U)

The intent of this initiative is to utilize the Shuttle and an upper stage to dispose of the nuclear waste products of nuclear power generating systems into deep space, rather than storing the highly toxic and very long-lived radioactive wastes on the surface of the earth. The use of the Shuttle, a large Tug, and specially constructed waste containers could assure that future environmental damage from nuclear waste entering the ecosystem is eliminated.

NUCLEAR WASTE DISPOSAL (CS-4) (U)

- **PURPOSE**
  To permanently dispose of nuclear wastes without environmental damage.

- **RATIONALE**
  Wholesale use of nuclear generating plants for electric power will result in large amounts of highly toxic and long lived radioactive wastes.

- **CONCEPT DESCRIPTION**
  Wastes are packed in containers with shielding and cooling, and put into earth escape trajectories by shuttle and velocity stages.

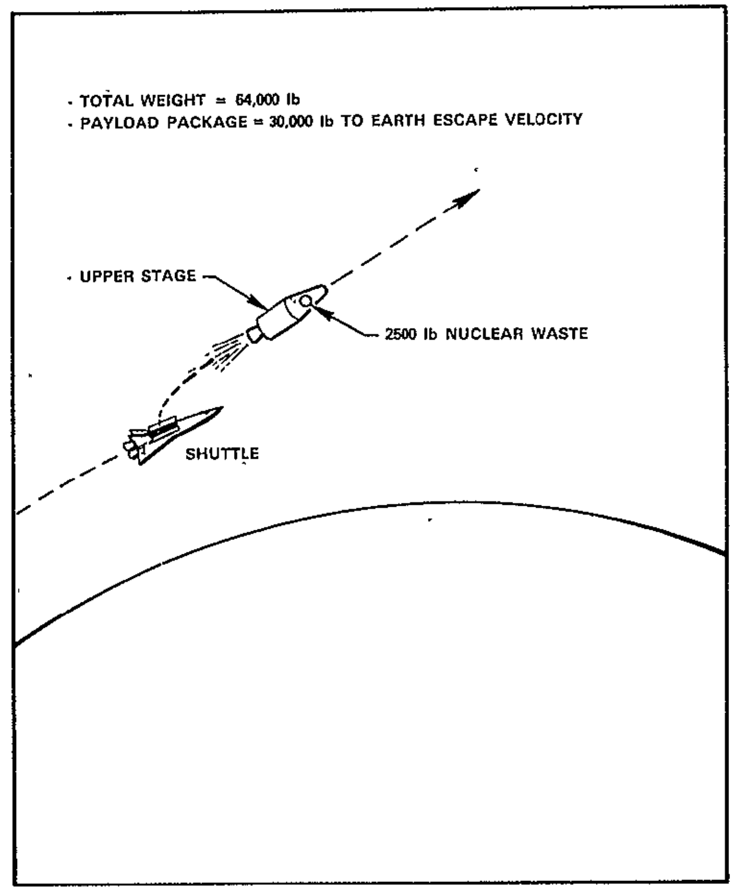
- **CHARACTERISTICS**

• WEIGHT	64,000 lb
• SIZE	15 x 60 ft
• RAW POWER	4 kW
• ORBIT	Escape
• CONSTELLATION SIZE	--
• LIFE/SERVICING PERIOD	--
• TIME FRAME	1990
• IOC COST	430 M

- **PERFORMANCE**
  2500 lb of waste per flight at $15 million per flight ($6000/lb). Cost increase to electrical consumer = 2%.

- **BUILDING BLOCK REQUIREMENTS**

• TRANSPORTATION	Shuttle and large tug
• ON-ORBIT OPERATIONS	No unusual requirements
• SUBSYSTEMS	Shielding/encapsulation
• TECHNOLOGY	Safety/thermal control
• OTHER	None

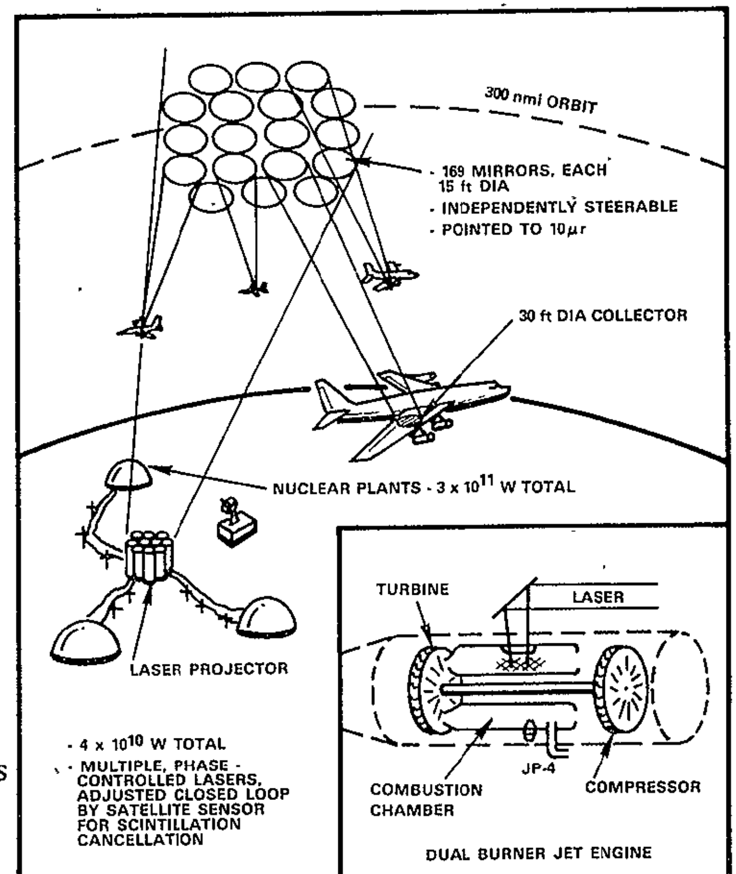


CS-5 - Aircraft Beam Powering

The intent of this initiative is to power large commercial aircraft for unlimited flight time and remove their dependency on petroleum. Laser energy is generated on the ground and is beamed via space mirrors on a satellite to aircraft in flight. This laser would be powered by nuclear power plants on the ground in the "near term," but eventually could be space based and powered by nuclear or solar energy in space. The laser energy is beamed to a collector on the upper surface of the aircraft to the engines. The engines are somewhat similar to conventional jet engines, but instead of energy being supplied to inlet air by the combustion of jet fuel, the energy is supplied by the absorption of the focused laser beam. The heated air drives the turbine/compressor as well as the aircraft. In this application, some jet fuel must be carried by the aircraft for conditions where the aircraft is under cloud cover thick enough that the laser will not penetrate, typically in some takeoff and landing situations. The power delivered to each aircraft is 10-50 megawatts.

The total electrical energy required is a significant fraction of that which supplies the entire electrical needs of the United States today. The lasers are of an unprecedented high power, but there are no physical limitations identified to date which would preclude their construction. The space mirror complex may be viewed as an energy common carrier, with the energy supplied either from the ground or from space, manipulated and directed in space.

AIRCRAFT BEAM POWERING (CS-5) (U)



- **PURPOSE**
  To provide an alternative to oil as a source of energy for powering commercial transports.

- **RATIONALE**
  Oil is a limited resource, becoming more expensive rapidly.

- **CONCEPT DESCRIPTION**
  Jet turbines are operated by heating air with laser beams projected to each aircraft by multi-mirror satellites. Laser on ground powered by nuclear reactors provides energy.

- **CHARACTERISTICS**

• WEIGHT	2,000,000 lb
• SIZE	169 mirrors, each 15 ft dia
• RAW POWER	0.5 kW/mirror
• ORBIT	300 nmi, 45^0 inclin.
• CONSTELLATION SIZE	100
• LIFE/SERVICING PERIOD	10/3 Years
• TIME FRAME	2000
• IOC COST	67.0 B

- **PERFORMANCE**
  2000 large jet aircraft powered continuously (30% duty cycle) at 10-50 MW/aircraft. Break-even with oil operations at 50¢/gal.

- **BUILDING BLOCK REQUIREMENTS**

• TRANSPORTATION	Shuttle and SEPS
• ON-ORBIT OPERATIONS	Manned Servicing Unit; orbital assembly
• SUBSYSTEMS	Attitude control; mirrors; processors; crosslink; thermal control
• TECHNOLOGY	Large high temp mirrors; radiators; pointing and tracking sensors; LSI processor
• OTHER	Ground high energy laser; atmospheric scintillation correction, closed loop

CS-6 - City Night Illuminator

The intent of this initiative is to use thin-film reflectors in orbit to reflect sunlight for the purpose of illuminating urban areas at night, saving the energy otherwise put into street lighting. From synchronous orbit, the smallest size ground area that can be so illuminated is 180 miles in diameter, due to the angular size of the sun as seen from the earth. A reflecting area equivalent to 100 mirrors, each 300 feet square, is required to provide an illumination equivalent to ten times that of the full moon in the absence of clouds. In the presence of light cloud cover, scattering will provide illumination, though of reduced intensity. The mirrors are attitude controlled and must track the sun to stabilize the image on the ground. Though they are large, they need not be heavy, nor need their optical figure be good. In order not to spread the image of the sun more than ten percent beyond the 180 n mi area, the surface tolerance can be as great as ± one foot in a 300-foot reflector, and the mirror construction is not difficult.

CITY NIGHT ILLUMINATOR (CS-6) (U)

- **PURPOSE**
  To provide night lighting without earth-based energy, pollution, street lights, cables, trenches, etc.

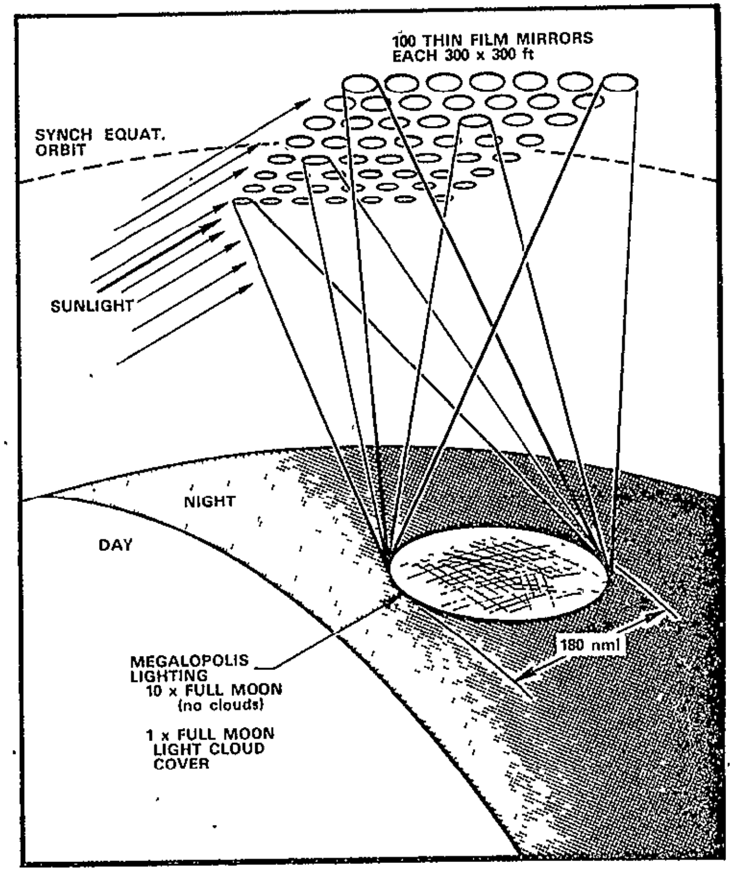
- **RATIONALE**
  Alternative energy sources needed.

- **CONCEPT DESCRIPTION**
  Sunlight reflected by pointing large mylar reflectors. Spot size determined by angular size of sun.

- **CHARACTERISTICS**

• WEIGHT	150,000 lb
• SIZE	100, 300-ft dia each
• RAW POWER	250 W
• ORBIT	Synch. Equat.
• CONSTELLATION SIZE	1
• LIFE/SERVICING PERIOD	10/3 Years
• TIME FRAME	1990
• IOC COST	1.1 B

- **PERFORMANCE**
  Ten times full moon provided (no clouds); full moon provided (heavy cloud cover).



- **BUILDING BLOCK REQUIREMENTS**

• TRANSPORTATION	Shuttle and large tug
• ON-ORBIT OPERATIONS	Automated Servicing Unit
• SUBSYSTEMS	Attitude control; structures; sensors
• TECHNOLOGY	Large optical reflector; pointing and tracking sensor
• OTHER	None

CS-10 - Vehicular Speed Control (U)

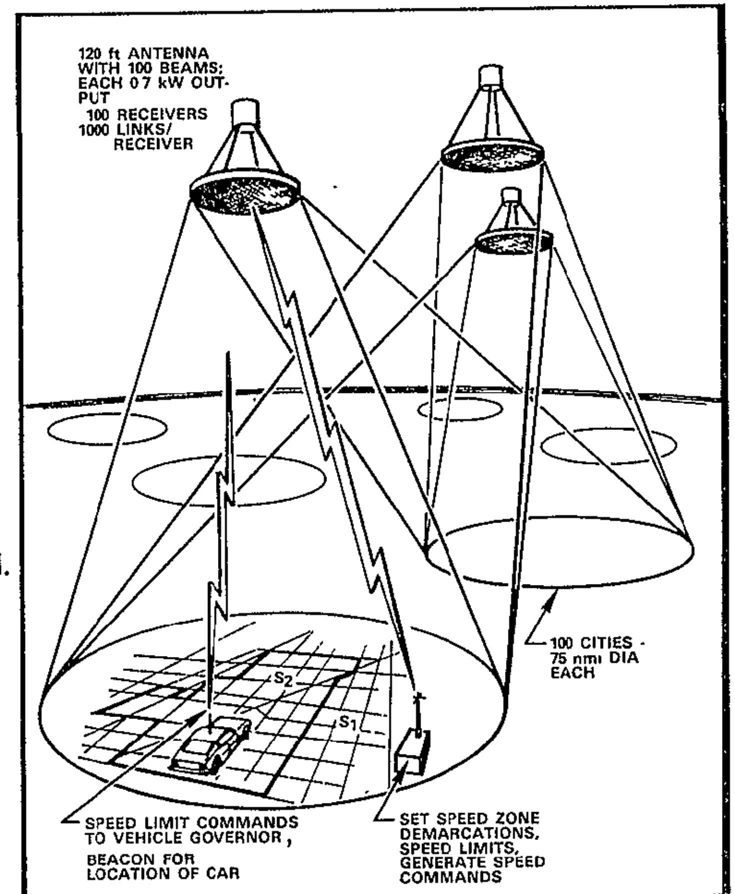
The intent of this initiative is to place positive limits, rather than administrative or legal limits, on the speeds at which automobiles may be driven on the streets. The technique envisioned is to require a radio-controlled engine governor as well as a small radio beacon transmitter on every vehicle. The location of each vehicle is determined by a ground station using time difference of arrival of the beacon signal transponded by the four satellites, and when the vehicle's location is determined to lie inside of any particular speed boundaries desired, the engine governor is commanded not to allow a speed in excess of that legally permitted in that zone. The demarcation of zones is set by software in a ground computer and is readily changed by a program change. The location of each car can be determined accurately to less than 50 - 100 feet and its speed limit controlled positively and continuously by the ground station through the satellite system.

VEHICULAR SPEED CONTROL (CS-10) (U)

- **PURPOSE**
  To establish positive vehicle speed control zones in cities by radio control of vehicle engine governors.

- **RATIONALE**
  Excessive speed is a major contributor to traffic accidents and injuries. With positive control, speeding is impossible.

- **CONCEPT DESCRIPTION** - Each vehicle has a small radiobeacon and a command receiver connected to a commandable speed governor. The location of each vehicle is determined by multiple satellite reception of the beacon. Commands are generated by computer on the ground.



- **CHARACTERISTICS**

• WEIGHT	10,000 lb
• SIZE	120-ft dia antenna
• RAW POWER	200 KW
• ORBIT	Synch. Equat. + Incl.
• CONSTELLATION SIZE	3
• LIFE/SERVICING PERIOD	10/3 Years
• TIME FRAME	1990
• IOC COST	610 M

- **PERFORMANCE**
  Vehicle speed controlled to ±1 mph. Provision for one million cars in each of 100 cities (100 million total channels).

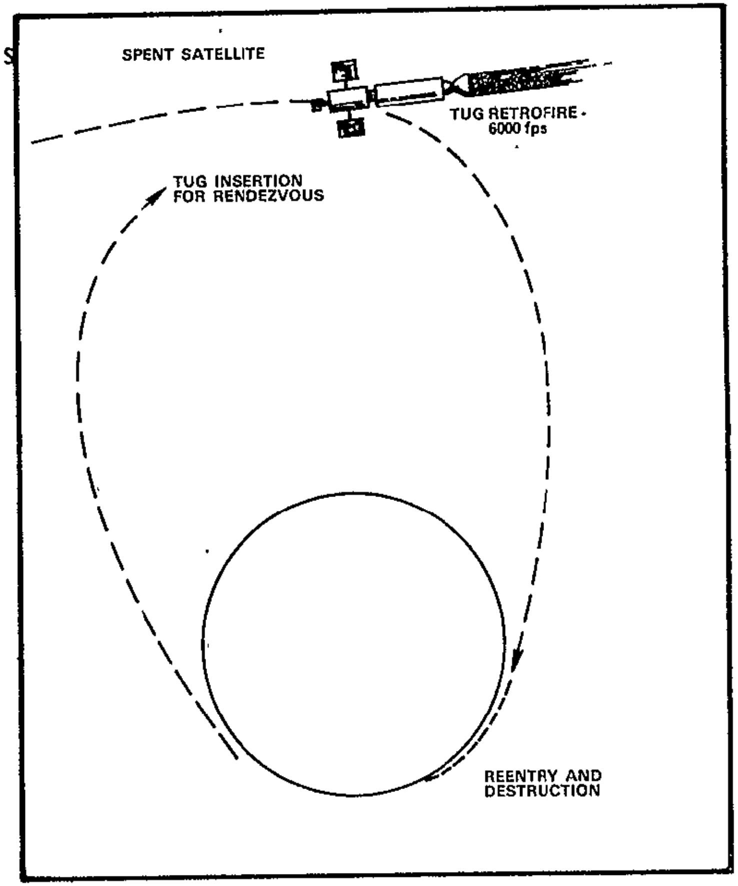
- **BUILDING BLOCK REQUIREMENTS**

• TRANSPORTATION	Shuttle and large tug
• ON-ORBIT OPERATIONS	Automated Servicing Unit; Assemble in Orbit
• SUBSYSTEMS	Attitude control; antenna; RF power DC power, channelized transponder
• TECHNOLOGY	Large multibeam antenna; power tubes, channelization techniques; large-scale multiple access
• OTHER	None

CS-11 - Space Debris Sweeper (U)

The intent of this initiative is to remove spent stages, satellites no longer considered useful, pieces of debris such as bolts, bands, shields, fairings, etc., from near-Earth space in order to reduce the danger of collisions. Such dangers will increase with time and increasing space use. The initiative dedicates a Tug permanently stationed in orbit. The Tug performs a rendezvous with the spent satellite or debris and applies a retrofire burn to drop the perigee of the debris to 100 nmi or less, such that its orbit will decay and the object will reenter within some reasonable time, such as a few weeks. An alternate technique is to add velocity so the object escapes. The latter may well minimize propellant expenditures for high altitude junk. The Shuttle is used to resupply propellants to the Tug so that it may perform multiple deorbit burns, reinject itself into stable orbits, and perform the required rendezvous with space junk.

SPACE DEBRIS SWEEPER (CS-11) (U)



- **PURPOSE**
  To remove expended satellites and debris from synchronous equatorial corridor where they pose a long-term collision threat.
- **RATIONALE**
  Synchronous equatorial corridor is becoming very crowded and could be dangerous in future.
- **CONCEPT DESCRIPTION**
  Use tug to impart ΔV to debris to drop its perigee to <100 nmi. Debris will reenter within weeks. One orbit later, tug re-injects itself into S E orbit. Tug resupplied by shuttle.
- **CHARACTERISTICS**

• WEIGHT	500,000 lb propellant
• SIZE	Tug
• RAW POWER	1.5 kW
• ORBIT	Up to Synch. Equat.
• CONSTELLATION SIZE	1
• LIFE/SERVICING PERIOD	N/A
• TIME FRAME	1985
• IOC COST	130 M

- **PERFORMANCE**
  500,000 lb of propellant will deorbit 100 satellites of 5000 lb each.

- **BUILDING BLOCK REQUIREMENTS**

• TRANSPORTATION	Shuttle and Tug
• ON-ORBIT OPERATIONS	No unusual requirements
• SUBSYSTEMS	No unusual requirements
• TECHNOLOGY	No unusual requirements
• OTHER	None

CS-12 - Ozone Layer Replenishment/Protection (U)

This initiative addresses the potential problem of depletion of the Earth's ozone layer, with the consequent increase of ultra-violet radiation on the surface resulting in varied harmful effects. Even though the phenomenology is not yet completely understood, it appears that freon gases liberated from aerosol spray cans, as well as oxides of nitrogen liberated from very high altitude aircraft can cause the ozone concentration to fall over a period of many years by a very complex interaction with the equilibrium reactions in the upper atmosphere, which reduce the ozone concentration. In this initiative a micro-encapsulated chemical, yet to be synthesized, would be sprayed from a low flying satellite or space shuttle and would disperse and settle through the ozone region. The encapsulation would be designed so as to evaporate near the lower end of the ozone region releasing the chemical. The characteristics desired for this special chemical would be: it should have a high affinity for the freon radical and a low affinity for oxygen, ozone, and the other components in the equilibrium reactions in the region; it would have to have a low potential for disociation under sunlight; and it would have to be stable over periods measured in years.

This chemical would bind to the freon radicals and deactivate them insofar as the ozone equilibrium reactions are concerned. A single application of the chemical would last for many years due to the low vertical diffusion rates at the altitudes of the layer. The quantity required could be fairly small since the chain reaction of the radical would be broken by the new chemical. The phenomenology of the ozone layer formation and its depletion are under active study currently. Synthesis of the freon-radical-active compound necessary for this initiative is speculative at this time. However, the possibility exists that this very important world problem could be amenable to solution from space. The solution to the oxides of nitrogen from aircraft would seem to be in controls at the source.

OZONE LAYER REPLENISHMENT/PROTECTION (CS-12) (U)

- **PURPOSE**
  To eliminate the depletion of the ozone layer from "freon" compounds.

- **RATIONALE**
  The ozone concentration in the layer is decreasing dangerously due to freons released by spray cans and industry.
- **CONCEPT DESCRIPTION**
  Space shuttle or suitable vehicle dispenses a chemical which settles and binds to the freon radicals in the lower ozone layer, deactivating them.

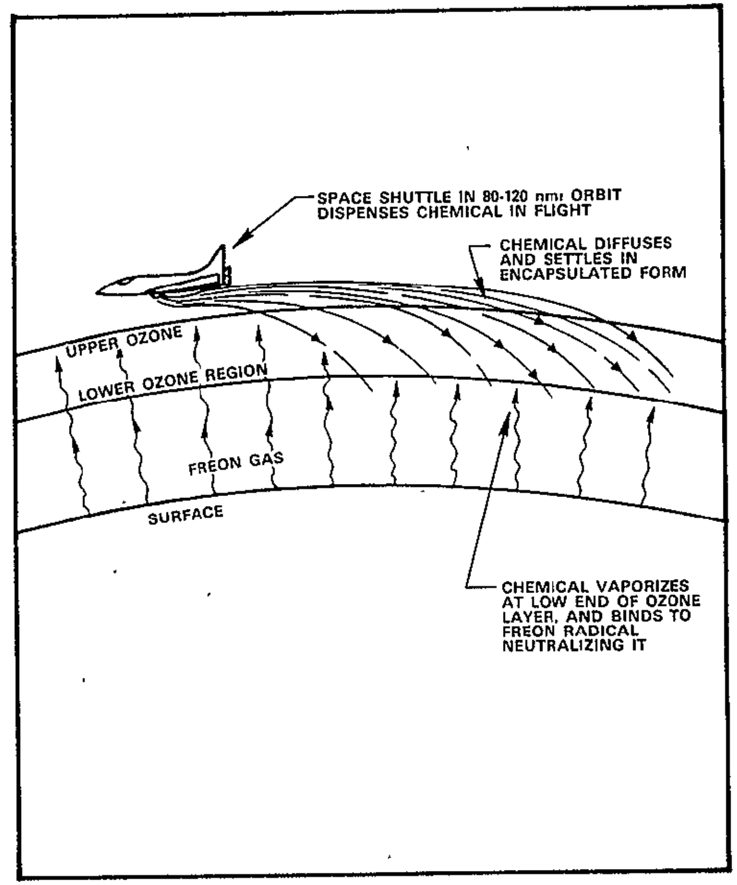
- **CHARACTERISTICS**

• WEIGHT	8,000,000 lb
• SIZE	---
• RAW POWER	---
• ORBIT	80-120 nmi polar
• CONSTELLATION SIZE	1
• LIFE/SERVICING PERIOD	every 10 years
• TIME FRAME	1985
• IOC COST	1.7 B

- **PERFORMANCE**
  Ozone layer replenished, protected for 10+ years by dispensing of 4000 tons of chemical.

- **BUILDING BLOCK REQUIREMENTS**

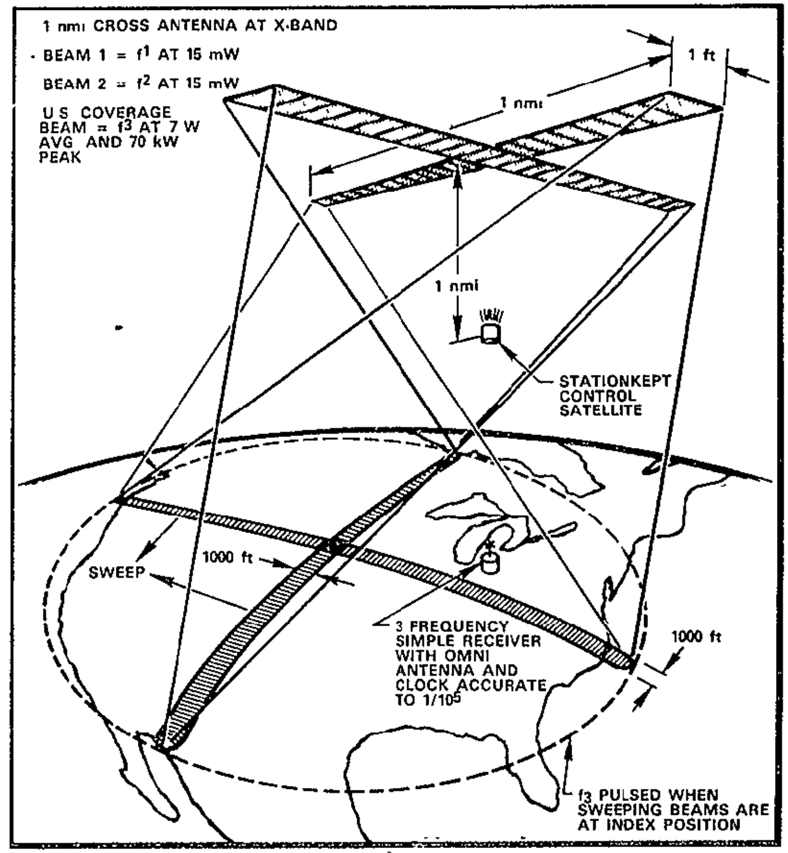
• TRANSPORTATION	LLV or Shuttle
• ON-ORBIT OPERATIONS	No unusual requirements
• SUBSYSTEMS	No unusual requirements
• TECHNOLOGY	No unusual requirements
• OTHER	Phenomenology of ozone layer depletion; synthesis of freon-radical active compound.



CS-13 - Inexpensive Navigation System (U)

The intent of this application is to reduce the complexity and therefore the cost of receivers for position location by placing a larger burden on the spacecraft used in generating the signals used for navigation. Thus the user equipment, which represents the largest investment in navigation systems fielded to date, could become much smaller and cheaper. In this initiative, very narrow swept fan beams are generated by a crossed array in space. The beams are swept across the country in a repetitive fashion, causing pulses to be generated in a receiver when the beams sweep past it. The beams subtend 1000 feet on the Earth, and their center can be determined to better than 100 feet by a simple receiver. A U.S. coverage beam is caused to transmit a pulse at the time when each fan beam is at its index position. The delay between the receipt of the index pulse and the receipt of the pulses from the sweeping beams is directly translatable into position relative to the index point, accurate to 1/10 of a beam width or about 100 feet. No coding is required, and a simple two or three frequency receiver with an omni antenna and low accuracy crystal clock accurate to one part in 10^5 suffices. This space antenna would be stationkept multiple satellites with a stationkept control satellite for controlling the radiation pattern of each arm. It is estimated that user equipment could cost \$10 - \$100 with LSI circuitry throughout and mass production.

INEXPENSIVE NAVIGATION SYSTEM (CS-13) (U)



- **PURPOSE**
  To provide accurate user position location with very inexpensive user equipment
- **RATIONALE**
  Navigation system costs are dominated by user equipment costs.
- **CONCEPT DESCRIPTION**
  Narrow beams are swept over the U. S. by large phased arrays in space. Very simple receivers measure time elapsed between pulses received from start and swept beams.
- **CHARACTERISTICS**

• WEIGHT	1300 lb
• SIZE	1 nmi cross
• RAW POWER	10 kW
• ORBIT	Synch. Equat.
• CONSTELLATION SIZE	1
• LIFE/SERVICING PERIOD	3 Years
• TIME FRAME	1990
• IOC COST	130 M

- **PERFORMANCE**
  - User position located to ± 100 ft every 10 seconds.
  - User receiver can cost as little as 100 $ or less in mass production.
- **BUILDING BLOCK REQUIREMENTS**

• TRANSPORTATION	Shuttle or LLV, large Tug/SEPS
• ON-ORBIT OPERATIONS	Manned and automated servicing units
• SUBSYSTEMS	Stationkeeping, ACS, antenna
• TECHNOLOGY	Ion thrusts, adaptive RF phase control, laser master measuring unit
• OTHER	LSI receivers

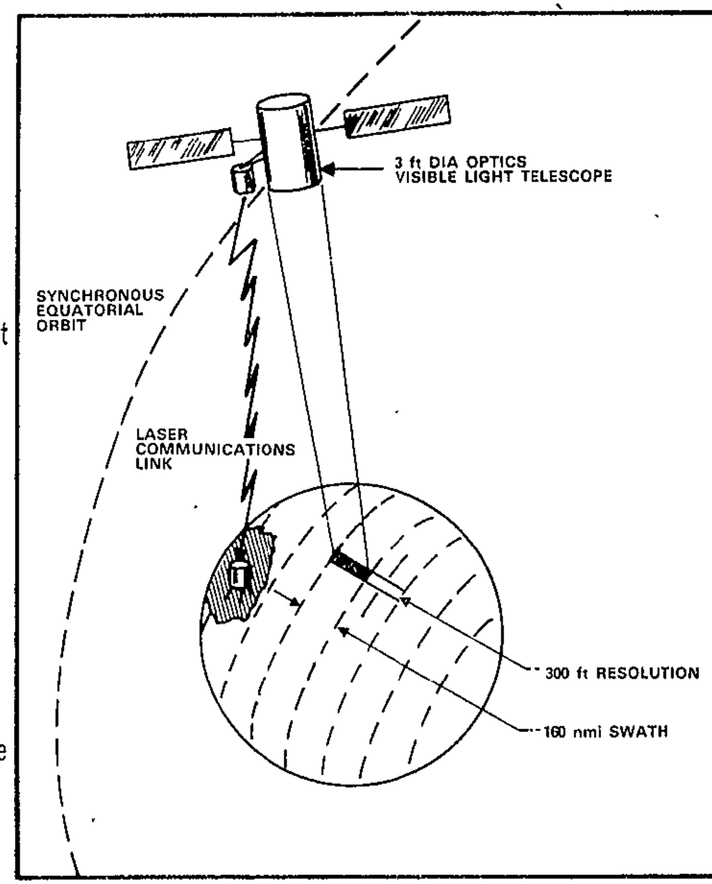
5

Pages 142 through 171 present descriptive data on initiatives MO-1 through MO-18. They are omitted for security classification reasons.

MO-20 - Synchronous Meteorological Satellite (U)

This initiative is to provide high resolution meteorological data similar to that obtained by current low-altitude metsats, but with the constant coverage obtainable from synchronous altitude. The information thus obtained would greatly facilitate global weather predictions. Optical sizes roughly 10 - 30 times those on low-altitude satellites are needed due to altitude increase.

SYNCHRONOUS METEOROLOGICAL SATELLITE (MO-20) (U)



- **PURPOSE**
  To collect worldwide atmospheric data for global weather prediction.

- **RATIONALE**
  High resolution and frequent coverage of globe are needed for forecasts.

- **CONCEPT DESCRIPTION**
  Optical sensor with 1 meter mirror collects visible light data on gross meteorological features. Same instrument makes spectrum measurements for detailed information on atmosphere.

- **CHARACTERISTICS**

• WEIGHT	3000 lb
• SIZE	5 x 20 ft
• RAW POWER	1 kW
• ORBIT	Synch. Equat.
• CONSTELLATION SIZE	3
• LIFE/SERVICING PERIOD	10/3 Years
• TIME FRAME	1985
• IOC COST	270 M

- **PERFORMANCE**
  Ground resolution 300 ft dia. Scan rate: Earth coverage in 20 sec for clouds, etc. Detailed measurements of spectrum every 200 sec.

- **BUILDING BLOCK REQUIREMENTS**

• TRANSPORTATION	Shuttle and tug
• ON-ORBIT OPERATIONS	Automated Servicing Unit
• SUBSYSTEMS	Laser
• TECHNOLOGY	Comm. link: 10 gigabits/sec from each satellite. Ground computer center.
• OTHER	Weather calculation method.

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Pages 174 through 235 present descriptive data on initiatives MO-21 through MO-24, MC-1 through MC-15, MW-1 through MW-8, and MS-1 through MS-12. They are omitted for security classification reasons.

A number of initiative ideas were collected which did not survive the initial screening as ideas that should be carried through to even the back-of-the-envelope analysis stage. Some of these were put into this category because the phenomenology is not well enough understood to define a program, even though the desirability of such an initiative might be evident. Others were included because even though the phenomenology might be understood, the technology requirements were either outlandish (even compared to some of the eye-popping initiatives which survived) or the function performed was not felt to be useful.

INITIATIVE IDEAS NOT DEFINED OR REJECTED

- CIVIL
  - / RADIOACTIVE CLOUD LOCATION MONITORING
  - / FEDERAL OFFICE MONITORING
  - / SURVEYING MARKER AID
  - / LASER PROPELLED ROCKETS
  - / ENERGY CONSUMPTION MONITORING
  - / AIRPORT FOG DISPERSAL
- MILITARY
  - / DEEP SPACE BASING OF RV DECOYS
  - / ASSURED DENIAL WEAPON
  - / RECALLABLE/RECOVERABLE OFFENSIVE WEAPONS
  - / GROUND-BASED SATELLITE INTERCEPTION
  - / COMMERCIAL COMSAT TRANSFER CONTROL
  - / AWACS/BATTLE CONTROL STATION
  - / ACTIVE LASER BACK BEAMER VIA STIMULATED LASER MODE
  - / SUBMARINE DETECTION BY CESIUM SEEDING
  - / SUB COMMUNICATIONS BY SPACE RF BEAM MIXING
  - / SUB COMMUNICATIONS BY MAGNETIC RESONANCE CESIUM

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RELATION OF INITIATIVES TO GOALS

E-0970

Not unexpectedly, there is a great correlation between the space functional goals which were outlined as requirements in the first part of the work and the initiatives themselves, and in fact, as is seen in the next three pages, there is at least one initiative in the catalog that contributes toward the attainment of almost every goal identified. These pages clearly show that space can be made relevant to the problems of society and this country in this time period.

RELATION OF INITIATIVES TO DESIRED SPACE FUNCTIONS

SPACE FUNCTIONS	SPECIFIC INITIATIVES
OBSERVATION	
• Resource Exploration	CO-1 Advanced Resource Pollution Observatory
• Pollution Monitoring	CO-1 Advanced Resource Pollution Observatory
• Weather Prediction and Control	MO-20 Advanced Synchronous Meteorological Satellite CO-11 Atmospheric Temperature Profile Sounder
• Disaster Warnings and Control	CC-2 Disaster Control Satellite
• Border Surveillance Against Illegal Entry	CO-8 Border Surveillance Intrusion Warning System
• Management of Ocean Resources	MO-17 Ocean Surveillance (Radar) MO-18 Ocean Surveillance (LWIR)
• Crop Prediction	CO-1 Advanced Resource/Pollution Observatory
• Forest Surveys and Management	CO-1 Advanced Research/Pollution Observatory CO-2 Forest Fire Detection

RELATION OF INITIATIVES TO DESIRED FUNCTIONS

SPACE FUNCTIONS	SPECIFIC INITIATIVES
COMMUNICATION	
• Nation-Nation Communications	CC-10 Diplomatic/U. N. "Hot lines"
• Transportation Control and Safety	CC-5 Transportation Services Satellites CO-9 Coastal Passive Radar
• Disaster Control	CC-2 Disaster Control Satellites
• Personal Communications, Emergency and Routine	CC-1 Global Search and Rescue CC-9 Personal Communications Satellite
• Police Communications and Control	CC-3 Urban/Police Wrist Radio
• Traffic Control	CS-10 Vehicular Speed Control CO-9 Coastal Passive Radar CC-5 Transportation Services System
• Better Communications Access Between People and Government	CC-7 Voting/Polling System CC-8 National Information Services CC-4 Electronic Mail Transmissions

RELATION OF INITIATIVES TO DESIRED FUNCTIONS

SPACE FUNCTIONS	SPECIFIC INITIATIVES
SUPPORT	
Energy Generation, Management and Delivery	CS-1 Nuclear Energy Plant in Space CS-2 Energy Generation Plant (RTG) CS-3 Energy Generation - Solar/Microwave CS-5 Aircraft Beam Powering
Space Processing	
Disposal of Wastes	CS-4 Nuclear Waste Disposal
Preservation of Ozone Layer	CS-12 Ozone Layer Replenishment/Protection
Preservation of Near-Space Environment	CS-11 Space Debris Sweeper
Night Illumination	CS-6 - City Night Illuminator - Police Searchlight
Control of Nuclear Materials	CO-7 Nuclear Fuel Location System
Pride in Significant Achievement	
Relief from Limits	- Research in Preparation for Space Habitation
Space Astronomical Observations and Experiments	CO-10 Astronomical Telescope

The possible contributions of the initiatives toward solution of the major problems in the civil area is divided into near-term and quite speculative columns in the facing page and the next two tables.

MAJOR PROBLEMS, CIVIL AREA 1980-2000	POSSIBLE CONTRIBUTION OF SPACE INITIATIVES: Moderate Risk		POSSIBLE CONTRIBUTION OF SPACE INITIATIVES: Quite Speculative
1. World Food Supply Predictable supply at relatively stable price.	Land:	Weather prediction aided by space observation Crop yield prediction from satellite observation. Crop health	Weather control, managed from space control center. Detailed temperature and pressure point functions in atmosphere for weather prediction
	Sea:	Good fishing area prediction by observation of sea conditions. Monitoring of fishing levels.	Detection of actual schools of fish by associated sea phenomena. Enforcing fishing levels.
2. World Energy Supply	None		Space disposal of nuclear wastes, permitting a fission power economy if terrestrial disposal is unsafe. Space solar-electric conversion, beamed to earth via microwaves. Laser powered aircraft by earth or space based laser, to conserve oil.
3. World Population Growth	No direct effects		Prospect of space colonization.

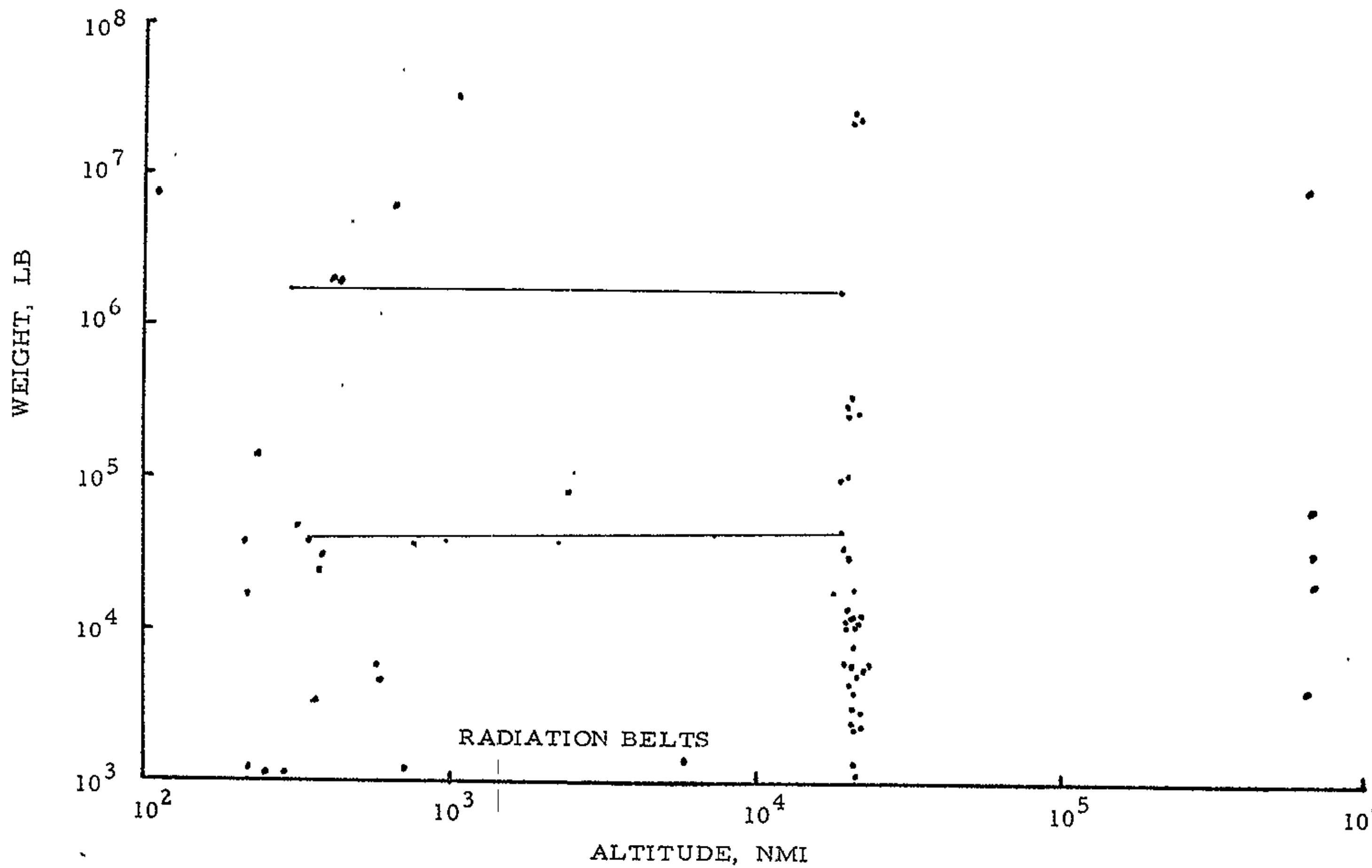
MAJOR PROBLEMS, CIVIL AREA 1980-2000	POSSIBLE CONTRIBUTION OF SPACE INITIATIVES: Moderate Risk	Quite Speculative
4. Environmental Protection	Pollution monitoring	Preservation of ozone layer against depletion by NO_x or freon.
5. General Safety	Disaster prediction and control of rescue and recovery.	
	Hurricane warning	Tsunami detection and prediction of progress.
	Flood warning	Earthquake prediction.
	Transportation safety	
	Traffic monitoring on land	Private auto traffic management
	Collision avoidance, sea-air, with inexpensive user equipment.	
6. Personal Fear of Bodily Harm	Enhanced police effectiveness by space communications.	
	U.S. border surveillance to control drug traffic.	
	Personal communication link to satellite to request help.	
	Night illumination from space on request of police.	

MAJOR PROBLEMS, CIVIL AREA 1980-2000	POSSIBLE CONTRIBUTION OF SPACE INITIATIVES: Moderate Risk	POSSIBLE CONTRIBUTION OF SPACE INITIATIVES: Quite Speculative
7. Nuclear Blackmail - Criminal or Dissident Group	None	Monitoring of nuclear fuel from space platform.
8. Loss of U. S. International Leadership	Shared output of space program results - weather, crops, disaster warning, science, aids in reestablishing good will towards U.S. and U. S. world leadership.	Establishment of manned space outposts, terrestrial, lunar, or lunar ground station. (Leadership effect is uncertain.)
9. Loss of Citizen Confidence in U. S. Government, and Disaffection for Government Goals	A well-run, total space program with economic benefits and aid to general safety contributes to ameliorating this problem. Specifically, a satellite polling system would give citizens more participation in government, helping build confidence.	

The illustration on the facing page shows the relationship between weight in orbit and orbital altitude for the initiatives considered in this report.

There are few satellites that the initiatives place inside the radiation belt regions, not only for the obvious reason of radiation sensitivity, but because of the reason that altitudes below a thousand miles are only used because optical sizes, antenna sizes, or RF powers become outlandish at greater altitudes. If, on the other hand, those factors are not limiting at medium altitudes, generally they will not be limiting at synchronous altitude either. Another reason is that the number of satellites required for continuous coverage of a zone or the globe decreases with increasing altitude, but does so fairly slowly above a few thousand miles altitude. Indeed, if a link can be designed for a few thousand miles altitude, it usually can also be designed for synchronous altitude obtaining many more benefits such as the lack of a need for tracking antennas, etc.

WEIGHTS AND ORBITS OF INITIATIVES



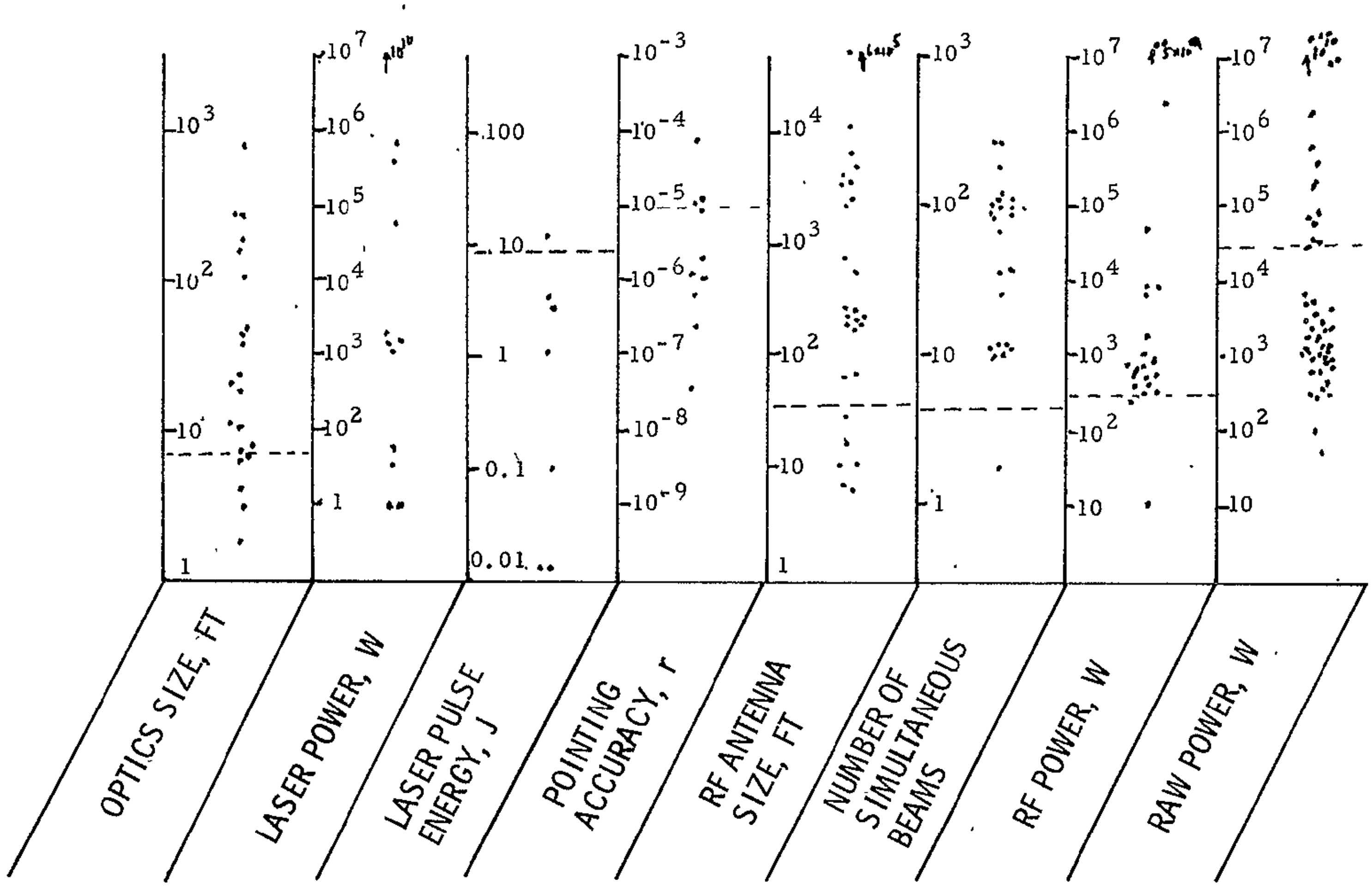
E-1007

The specific technology needs which are called for in the initiatives without any weight given to type, application, or function, are shown in this graph with one point representing the requirements of a given initiative. One initiative may give rise to more than one point on different graphs.

The dashed lines for each vertical graph represents today's rough state-of-the-art of the technology. It is seen that optical sizes called for are generally much larger than those supported today. The average power of lasers called for, however, is usually not in excess of that which has been experimentally proven today, except for one or two initiative cases. That is also the case for pulsed lasers where today's state-of-the-art is entirely adequate, provided the lasers are space qualified. Much more precise pointing accuracy is required than that demonstrated today.

In the RF antenna sizes, there is a dramatic call for much larger sizes than that supported today. This is also true of the number of simultaneous beams generated in an RF antenna, although the number of beams called for does not represent a great increase in the technology, it simply has not yet been done in space. The RF transmitted power in almost every case is higher than that demonstrated to date, although in only a few cases does it require new technology, since in many cases it can simply be achieved by paralleling devices fairly well understood today. Many of the raw power requirements are below those which have been demonstrated in Skylab to date, although in a few cases, such as in the solar power stations, clearly much more power is required. This is also true of some of the laser-powered devices in orbit, where raw power in the order of a few hundred thousand to a million watts is required. This graph gives a direction for the technology developments which are needed to accommodate the group of initiatives as a whole, though do not reflect the worth of any initiative or group over any other.

SUMMARY OF TECHNOLOGY NEEDS



The following sections discuss the building block subsystems, systems, and technologies required to support the initiatives identified in the first part of the work. An introductory discussion of the common aspects of the building blocks and technology is also presented.

BUILDING BLOCKS/COMMONALITY

The different types of commonality which apply in this task are illustrated on the facing page. These specific types of commonality were considered in developing a list of building blocks and technologies which will be identified for each initiative, in order to determine the common requirements between sets of initiatives.

COMMONALITY ASPECTS FOR SPACE SYSTEMS

A. COMMON PROCEDURES IN SPACE SYSTEMS' LIFE CYCLE	B. COMMON SUPPORT - SPACE SYSTEMS OR GROUND FACILITIES
1. Research for program 2. Technique tests, some in space 3. Fabrication and assembly suitable for space environment 4. Functional initialization 5. Routine maintenance 6. Repair 7. Modification 8. Resupply or replenishment 9. Function termination 10. Removal	1. Research Earth labs Space labs 2. Technique tests Space flight tests Universal space test bed 3. Fabrication and assembly Ground facility Space facility Proximity system Specialized fabrication Assembly techniques with standard connectors Assembly with specialized connectors
C. COMMONALITY OF SATELLITES	**D. COMMONALITY IN SPACECRAFT SUPPORT FUNCTIONS**
1. Single satellite - multiple user of same function 2. Separate identical satellites for different users 3. Different satellites, common subsystems 4. Different satellites, but with elements of common technology 5. Different satellites but common procedures in life cycle (see category A)	1. Structure 2. Electric power management 3. Thermal control 4. Pointing systems 5. Command and control 6. Data processing 7. Observation sensors 8. Communication of data

This is the first of eight foldout tables in which the building block and technology requirements for each initiative are identified. Each table represents a set of initiatives categorized by whether it is military or civilian, and observation, communication, support, or weaponry. Each initiative is identified by code number and by a functional name. The building block and technology requirements are compiled from the initiative descriptions.

The transportation blocks include those candidate vehicle requirements to place the initiative into low orbit, to transfer it to high orbit if required, and to perform on-orbit operations including servicing, assembly, and/or special payload maneuvering if extensively required. In the building block categories, an X is placed in the matrix where a requirement appears to exist. If there is no clear choice among the various candidates identified, a C is put in those columns between which there appears to be a choice. In general, maximum utility was made of the Space Shuttle, with the large launch vehicle being shown as clearly required only if the number of flights needed to establish a given initiative exceeded several hundred. More specific ground rules which were followed in preparation of these matrices are detailed in Appendix B, as are the performance capabilities assumed for the various classes of boosters and stages.

The technology items identified include the mission equipment, satellite housekeeping equipment, and support equipment technologies. Only those technologies in which unusual requirements could be identified, or where the state-of-the-art does not clearly fill the needs of the initiative, are marked. Blanks exist in those areas which can be met with today's technology or with reasonable near-term engineering developments.

The category column refers to a general risk categorization, where a numeral 1 refers to near-term technology which can be developed with low risk. A numeral 2 refers to far-term technology, where the engineering developments are expected to be long, costly, and risky, but are based on phenomenology which is reasonably well understood, or where no great surprises are expected; and Category 3, where the risk and length of development depend on the outcome of more detailed phenomenological investigations, which could swing the initiative into Category 1 or 2, or reject it entirely.

BUILDING BLOCK AND TECH

CODE	NAME	BUILDING BLOCKS														CATEGORY	REMARKS
		LOW ORBIT			HIGH ORBIT					ON-ORBIT							
										ASSEMBLY/ SERVICING				P MAN			
		SMALL EXPENDABLE	SHUTTLE	LLV	TUG	MANNED TUG	SEPS	LARGE SEPS	NUCLEAR	SHUTTLE ATTACHED MANIPULATOR	AUTOMATED SERVICING UNIT	MANNED SERVICING UNIT	TELEOPERATOR SERVICING UNIT	CHEMICAL	SEPS		
CO-1	ADVANCED RESOURCE/POLLUTION OBSERVATORY		X							C		C	C			I	
CO-2	FOREST FIRE DETECTION		C	C		X					C					I	
CO-3*	FISH SCHOOL DETECTION																
CO-4*	PERSONAL LOCATOR																
CO-6	U. N. TRUCE OBSERVATORY		X							C		C	C			I	
CO-7	NUCLEAR FUEL LOCATION		X		X						C					III	
CO-8	BORDER SURVEILLANCE		X		X						C	C	C			I	
CO-9	COASTAL PASSIVE RADAR		X			X					C	C	C			II	
CO-10	ASTRONOMICAL TELESCOPE		X							C		C	C			II	
CO-11	ATMOSPHERIC TEMP PROFILE SOUNDER		X							C		C	C			II	

* To be supplied.

FOLDOUT FRAME

ORIGINAL PAGE IS OF POOR QUALITY

FOLDOUT FRAME 2

BUILDING BLOCK AND TE

CODE	NAME	BUILDING BLOCKS: LOW ORBIT: SMALL EXPENDABLE	SHUTTLE	LLV	HIGH ORBIT: TUG	LARGE TUG	SEPS	LARGE SEPS'	NUCLEAR	ON-ORBIT: ASSEMBLY/ SERVICING: SHUTTLE ATTACHED MANIPULATOR	AUTOMATED SERVICING UNIT	MANNED SERVICING UNIT	TELEOPERATOR SERVICING UNIT	PAY MANEU: CHEMICAL	SEPS	LARGE SEPS	CATEGORY	REMARKS
CC-1	GLOBAL SEARCH AND RESCUE		X		X						X						I	
CC-2	DISASTER CONTROL - C&C		X		X		C	C			C	C	C				I	
CC-3	URBAN/POLICE WRIST RADIO		X		X		C	C			C	C	C				II	
CC-4	ELECTRONIC MAIL TRANSMISSION		X		X						C	C	C				I	
CC-5	TRANSPORTATION SERVICES SATELLITE		X		X												I	
CC-6*	ADVANCED TV BROADCAST																	
CC-7	POLLING AND VOTE COLLECTION		X		X		C	C			C	C	C				I	
CC-8	NATIONAL INFORMATION CENTER		X		X		C	C			C	C	C				I	
CC-9	PERSONAL COMMUNICATION SYSTEM		X		X		C	C			C	C	C				II	
CC-10	DIPLOMATIC/UN HOT LINE		X		X						C						I	
CC-11*	REMOTE 3D CONFERENCING																	

* To be supplied

FOLDOUT FRAME 1

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FOLDOUT FRAME 2

BUILDING BLOCK AND TEC

CODE	NAME	BUILDING BLOCKS																									CATEGORY	REMARKS
		LOW ORBIT					HIGH ORBIT							ON-ORBIT														
														ASSEMBLY/ SERVICING						PA MAN								
		SMALL EXPENDABLE	SHUTTLE	LLV			TUG	LARGE TUG	SEPS	LARGE SEPS	NUCLEAR			SHUTTLE ATTACHED MANIPULATOR	AUTOMATED SERVICING UNIT	MANNED SERVICING UNIT	TELEOPERATOR SERVICING UNIT			CHEMICAL	SEPS	LARGE SEPS						
CS-1	ENERGY GENERATION PLANT - NUCLEAR			X			C	C	C	C	C				C	C	C			C							II	
CS-2	ENERGY GENERATION PLANT - RTG			X				C	C	C	C				C	C	C			C							II	
CS-3	ENERGY GENERATION PLANT - SOLAR			X				C	C	C	C				C	C	C			C							II	
CS-4	NUCLEAR WASTE DISPOSAL		X					X																			II	
CS-5	AIRCRAFT BEAM POWER			X										C		C	C										II	
CS-6	NIGHT ILLUMINATOR - SOLAR		C				X								C												I	
CS-7*	SEARCHLIGHT FROM SPACE																											
CS-8	NIGHT SEARCHLIGHT - LASER		C	C				X							C												II	
CS-9*	ENERGY CONSUMPTION MONITORING																											
CS-10	VEHICULAR SPEED CONTROL		X					C	C	C					C	C	C										II	
CS-11	SPACE DEBRIS SWEEPER		X				C		C	C	C									C	C	C					II	
CS-12	OZONE LAYER REPLENISHMENT		X																								II	
CS-13	INEXPENSIVE NAV SYSTEM		X				X								X												II	

* To be supplied.

BUILDING BLOCK AND TECH

CODE	NAME	BUILDING BLOCKS: LOW ORBIT: SMALL EXPENDABLE	SHUTTLE	LLV	HIGH ORBIT: TUG	LARGE TUG	SEPS	LARGE SEPS	NUCLEAR	ON-ORBIT: ASSEMBLY/SERVICING: SHUTTLE ATTACHED MANIPULATOR	AUTOMATED SERVICING UNIT	MANNED SERVICING UNIT	TELEOPERATOR SERVICING UNIT	P/ MAN: CHEMICAL	SEPS	CATEGORY	REMARKS
MO-1			X		C				C		X			C		I	
MO-2*																	
MO-3			C	C		X					C					I	
MO-4			X		C		C				C	C	C			I	
MO-5*																	
MO-6			C	C		X					C	C	C			II	
MO-7			X		C	C					C					II	
MO-8			X							X						I	
MO-9			X		X									C		II	
MO-10			X		X											I	
MO-11			X				C	C								I	
MO-12*	(Deleted for security classification reasons)																
MO-13			X													I	
MO-14			X							X						II	
MO-15			X			X					C					II	
MO-16			X		X						X			C		I	
MO-17			X													I	
MO-18			X													I	
MO-19*																	
MO-20			X		X						X					II	
MO-21			X							X						II	
MO-22			X			X					X					II	
MO-23			X		X						X					II	
MO-24			X		X						X					II	

BUILDING BLOCK AND TECH

CODE	NAME	BUILDING BLOCKS																									CATEGORY	REMARKS
		LOW ORBIT					HIGH ORBIT							ON-ORBIT														
														ASSEMBLY/ SERVICING						PA MANE								
		SMALL EXPENDABLE	SHUTTLE	LLV			TUG	LARGE TUG	SEPS	LARGE SEPS	NUCLEAR			SHUTTLE ATTACHED MANIPULATOR	AUTOMATED SERVICING UNIT	MANNED SERVICING UNIT	TELEOPERATOR SERVICING UNIT			CHEMICAL	SEPS	LARGE SEPS						
MC-1			X				X								X												II	
MC-2			X				C				C				X					C							I	
MC-3			PIGGYBACK																								I	
MC-4			X				X		C	C	C									C							I	
MC-5			X				X								X												I	
MC-6	(Deleted for security classification reasons)		X				X	C	C	C	C				X												I	
MC-7			X																								III	
MC-8*																												
MC-9*																												
MC-10			C	C				X								C	C										II	
MC-11			X				X								X												I	
MC-12			X				X								X												I	
MC-13			X				C	C							C	C	C				X						II	
MC-14			X				X								X												I	
MC-15			X				X								X												II	

BUILDING BLOCK AND TECHNOL

CODE	NAME	BUILDING BLOCKS: LOW ORBIT			HIGH ORBIT					ON-ORBIT: ASSEMBLY/ SERVICING				PAY MANEU			CATEGORY	REMARKS
		SMALL EXPENDABLE	SHUTTLE	LLV	TUG	MANNED TUG	SEPS	LARGE SEPS	NUCLEAR		AUTOMATED SERVICING UNIT	MANNED SERVICING UNIT	TELEOPERATOR SERVICING UNIT	CHEMICAL	SEPS	NUCLEAR		
MS-1			X		X												II	
MS-2			X							X							I	
MS-3			X							X							I	
MS-4*																		
MS-5*																		
MS-6*	(Deleted for security classification reasons)																	
MS-7*																		
MS-8			X		X						X						II	
MS-9			X			X					C						II	
MS-10			X		X												III	
MS-11			X														I	
MS-12				X	X		C	C		C		C	C				III	
MS-13*																		

BUILDING BLOCK AND TECHN

CODE	NAME	BUILDING BLOCKS: LOW ORBIT: SMALL EXPENDABLE	LOW ORBIT: SHUTTLE	LOW ORBIT: LLV	HIGH ORBIT: TUG	HIGH ORBIT: LARGE TUG	HIGH ORBIT: SEPS	HIGH ORBIT: LARGE SEPS	HIGH ORBIT: NUCLEAR	ON-ORBIT: ASSEMBLY/ SERVICING: SHUTTLE ATTACHED MANIPULATOR	ASSEMBLY/ SERVICING: AUTOMATIC SERVICING UNIT	ASSEMBLY/ SERVICING: MANNED SERVICING UNIT	ASSEMBLY/ SERVICING: TELEOPERATOR SERVICING UNIT	PAY MANEU: CHEMICAL	PAY MANEU: SEPS	PAY MANEU: LARGE SEPS	CATEGORY	REMARKS
MW-1			X			X											II	
MW-2			X			X											II	
MW-3*																		
MW-4			C	C		X	C	C			C	C	C				II	
MW-5*																		
MW-6	(Deleted for security classification reasons)		X	X		C	C	C			C	C	C	C			II	
MW-7				X						C		C	C				II	
MW-8				X			C	C		C		C	C				II	
MW-9*																		
MW-10*																		
MW-11*																		
MW-12*																		

INITIATIVE CATEGORY	RISK CATEGORY	BUIL													
		LOW ORBIT			HIGH ORBIT					SUPPORT					
		SMALL EXPENDABLE	SHUTTLE	LLV	TUG	LARGE TUG	SEPS	LARGE SEPS	NUCLEAR	RESEARCH LABORATORY	UNIVERSAL TEST SATELLITE	SPACE FABRICATION	SPACE ASSEMBLY	SPACE SERVICING	MANNED SPACE STATION
MO	I	0	10	1	4	1	2	1	1	5	9	0	1	6	1
	II	0	10	1	5	4	0	0	0	7	8	0	2	10	1
	III	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MC	I	0	6	0	6	0	1	1	2	0	3	0	0	5	0
	II	0	4	1	3	2	0	0	0	2	4	0	2	4	2
	III	0	1	0	0	0	0	0	0	1	1	0	0	0	0
MW	I	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	II	0	4	4	0	4	3	3	0	4	6	0	3	4	2
	III	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MS	I	0	3	0	0	0	0	0	0	0	2	0	0	2	0
	II	0	3	0	2	1	0	0	0	1	2	0	1	2	0
	III	0	1	3	2	0	1	1	0	1	2	0	1	2	0
CO	I	0	4	1	1	1	0	0	0	1	3	0	1	4	0
	II	0	3	0	0	1	0	0	0	2	2	0	3	2	1
	III	0	1	0	1	0	0	0	0	0	1	0	0	0	0
CC	I	0	7	0	7	0	3	3	0	0	7	0	2	6	4
	II	0	2	0	2	0	2	2	0	0	2	0	1	2	2
	III	0	0	0	0	0	0	0	0	0	0	0	0	0	0
CS	I	0	1	0	1	0	0	0	0	0	1	0	1	1	0
	II	0	6	5	3	6	5	5	4	5	7	1	6	6	4
	III	0	0	0	0	0	0	0	0	0	0	0	0	0	0

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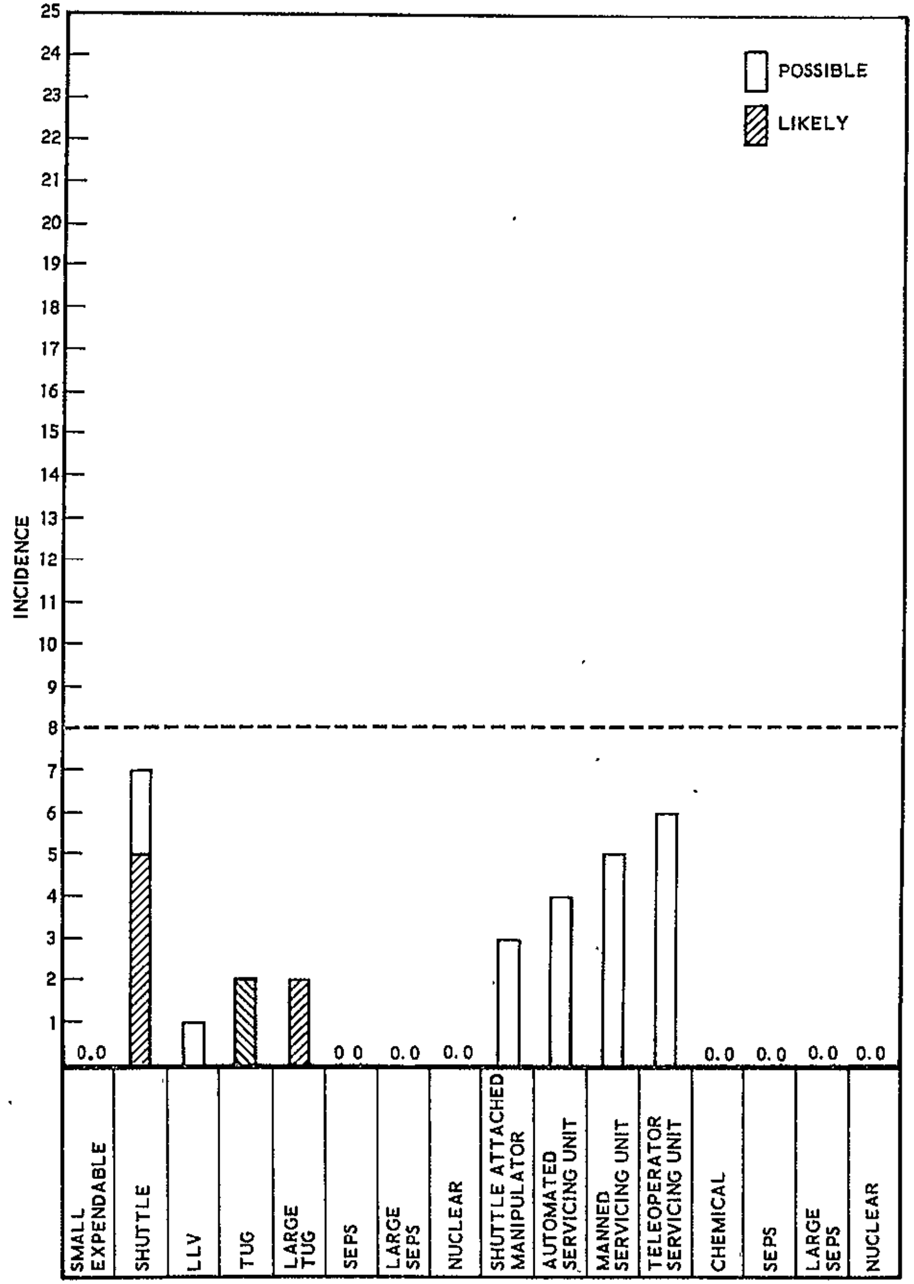
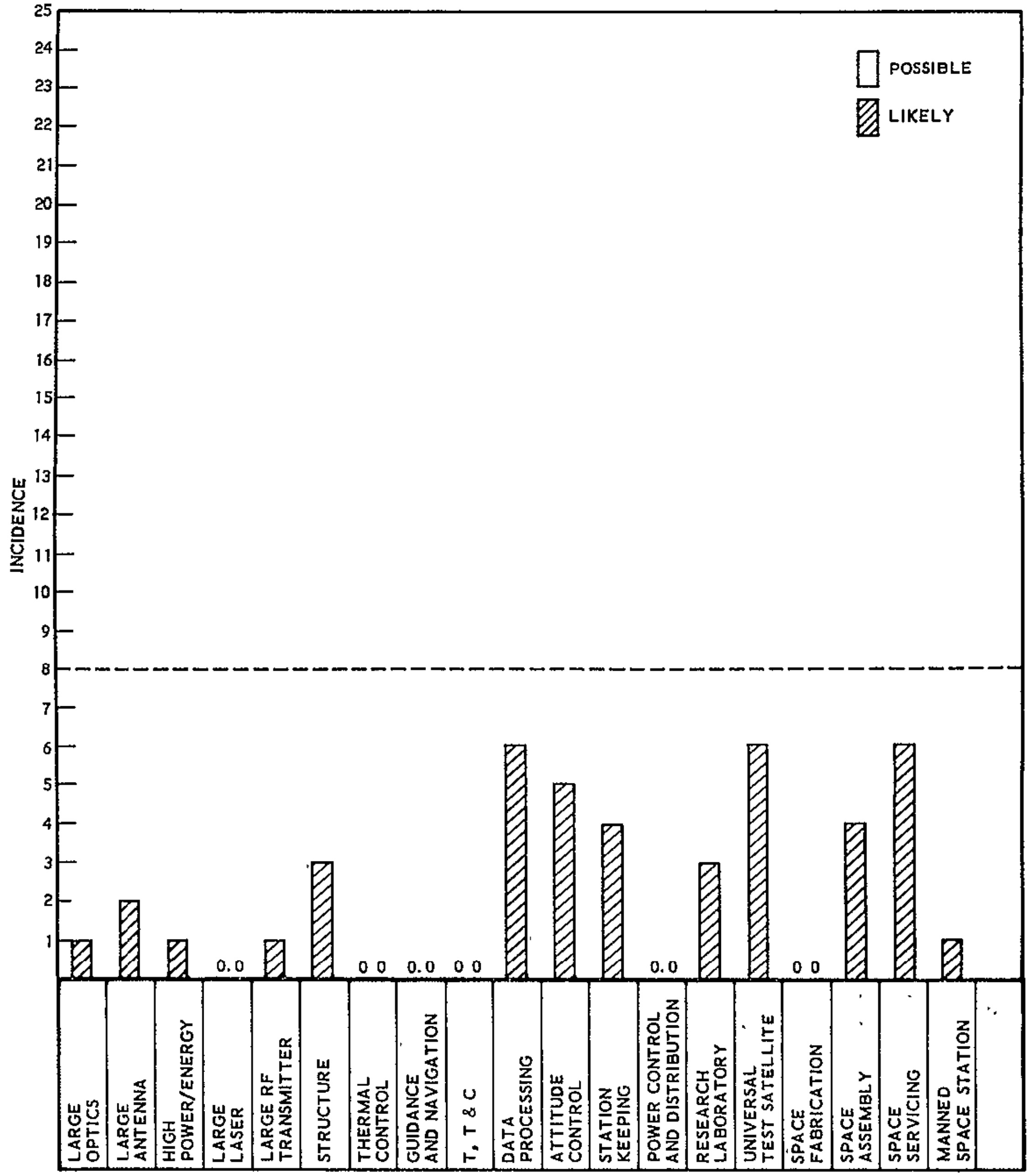
FOLDOUT FRAME 2

The next 19 sheets provide in summary form the building block and technology requirements abstracted from the past eight matrices for each class of initiatives. The information is presented in bar graph form, showing the incidence of the number of initiatives in each class which show a requirement for each building block or technology. Where the bars are solid, they indicate hard requirements as collected from the initiatives. The empty bars indicate that a choice existed between candidates for the same class of function. For instance the Shuttle and the large launch vehicle vie for the same mission. In the first case, the Shuttle is shown to be required in 10 out of 21 initiatives, and possibly required in all 21, with a choice possible in 11 initiatives between the Shuttle and the large launch vehicle. The solid part of the bar then represents a minimum requirement, and the top of the bar a possible maximum. Again, there is no weight given to any of the initiatives over any others, and all are assumed equally important, equally feasible, and equally desirable.

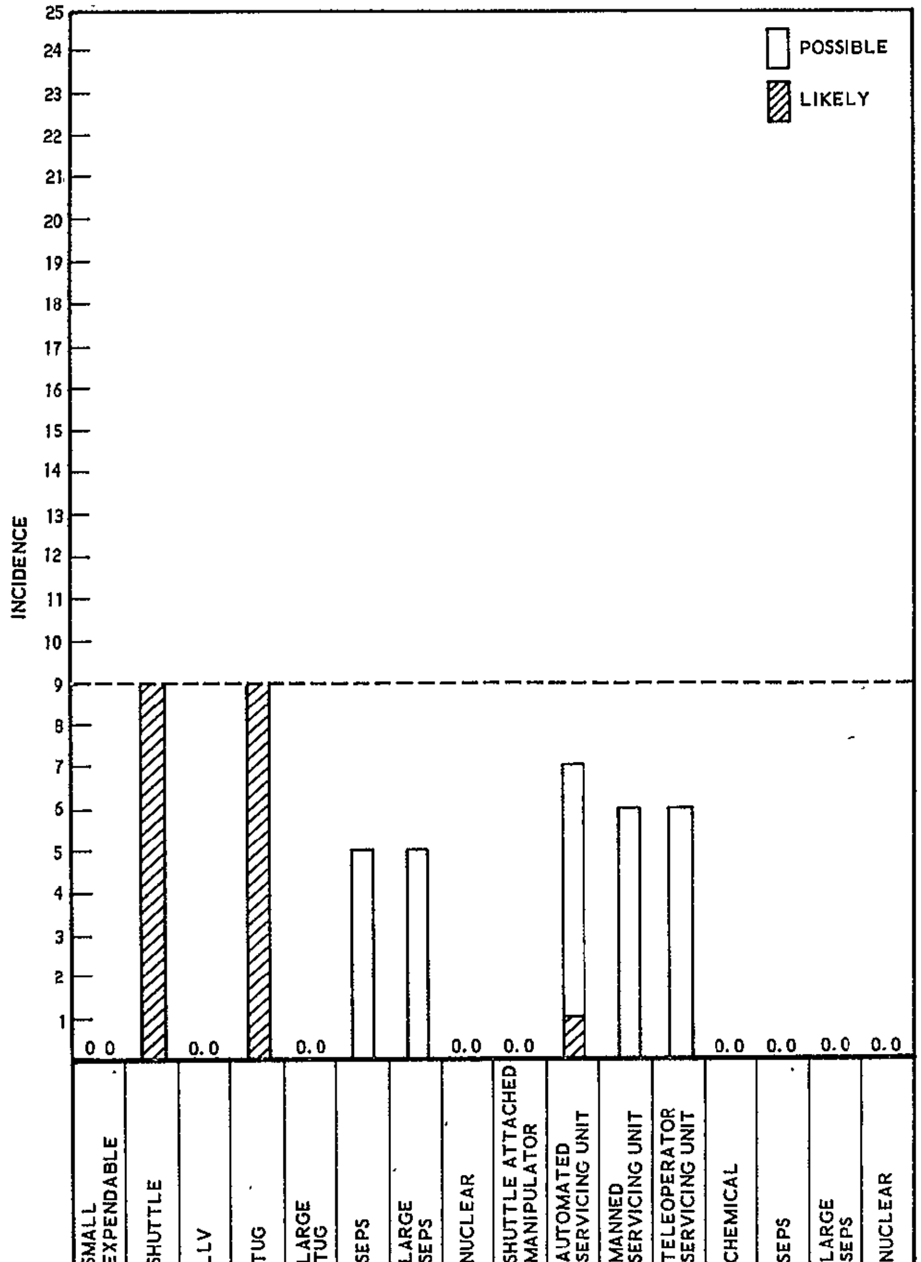
Building Block Requirements
CIVILIAN OBSERVATION



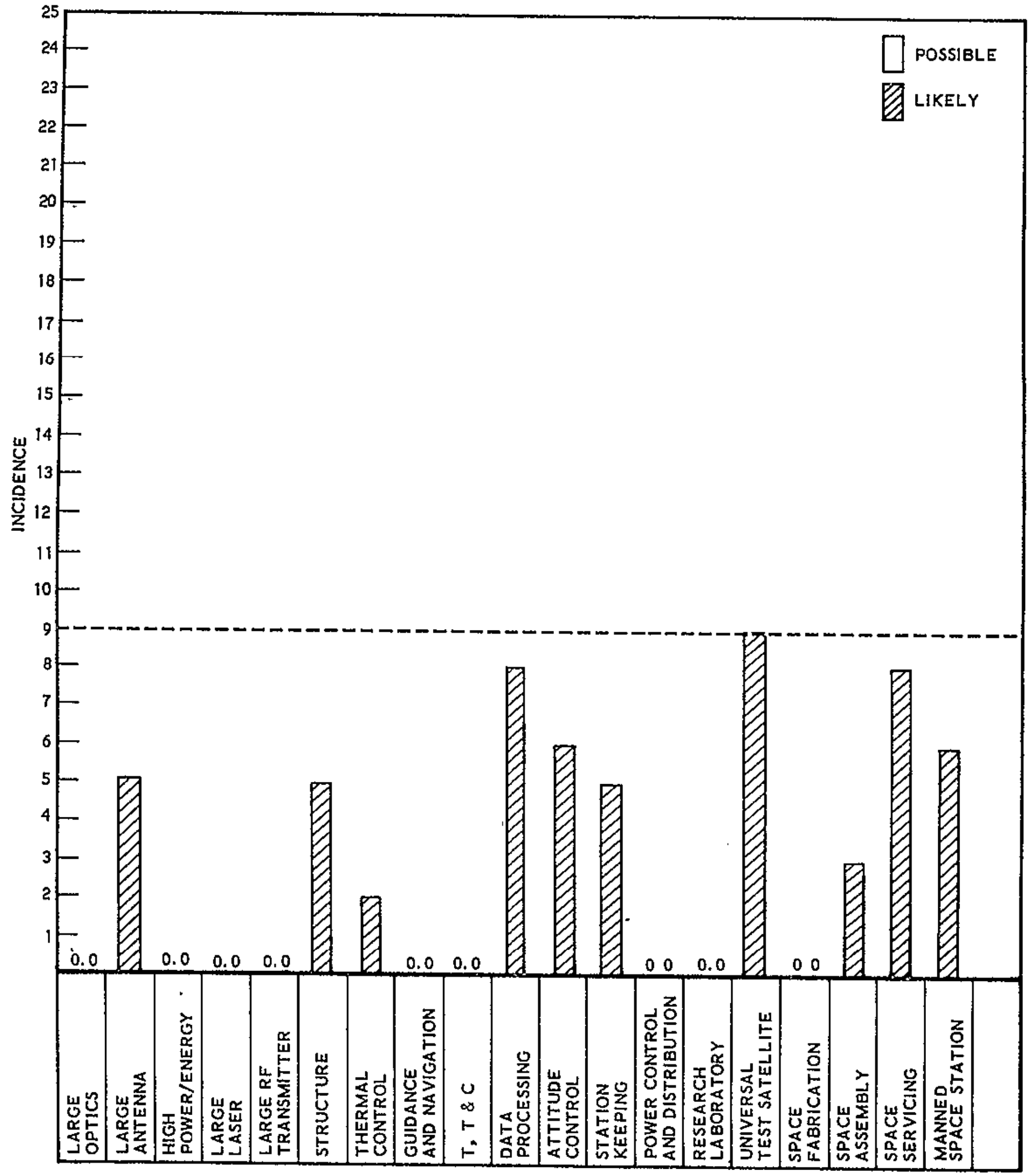
Technology Requirements
CIVILIAN OBSERVATION



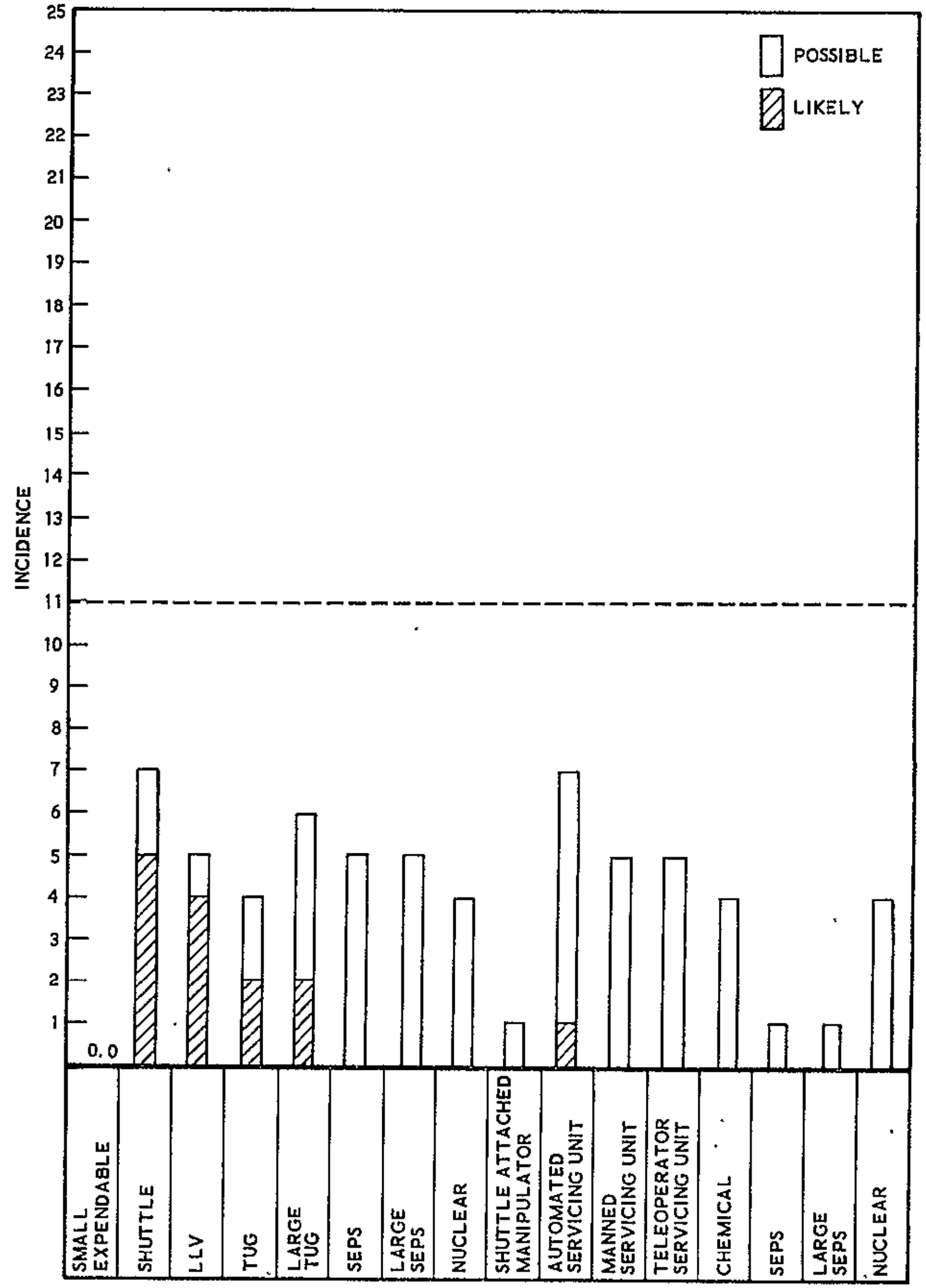
Building Block Requirements
CIVILIAN COMMUNICATIONS



Technology Requirements
CIVILIAN COMMUNICATIONS



Building Block Requirements
CIVILIAN SUPPORT



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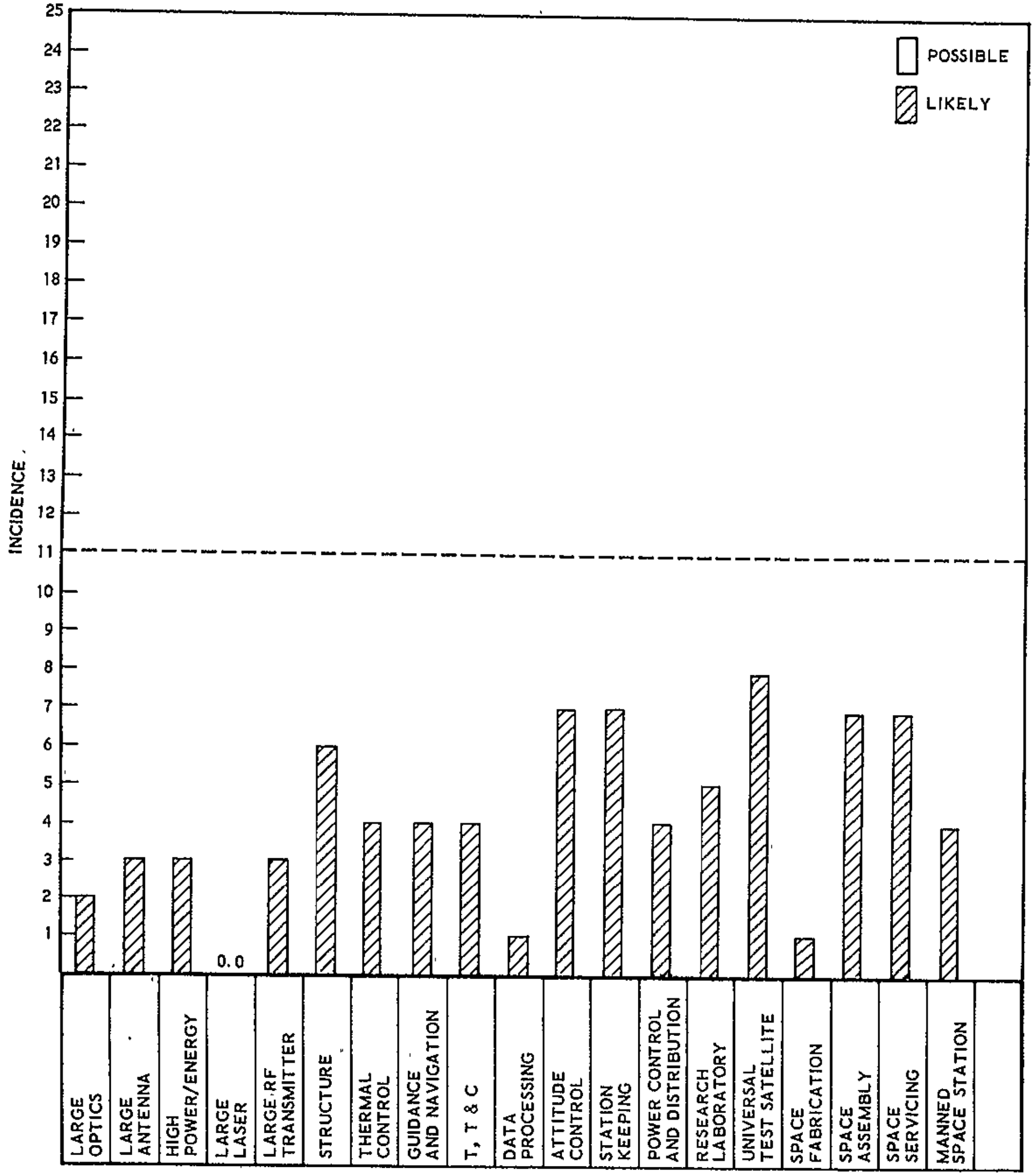
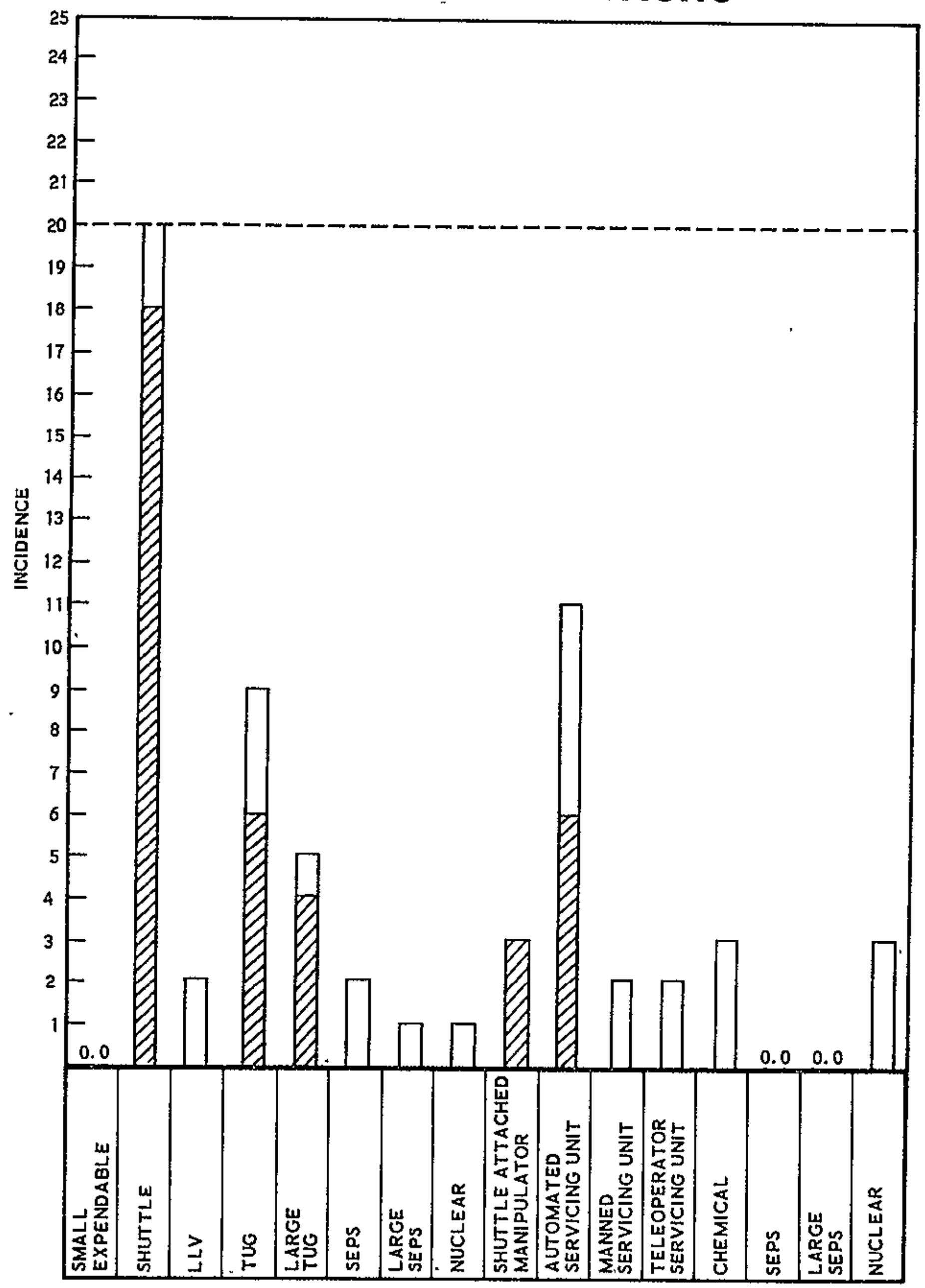
CIVILIAN SUPPORT



Building Block Requirements
MILITARY OBSERVATIONS



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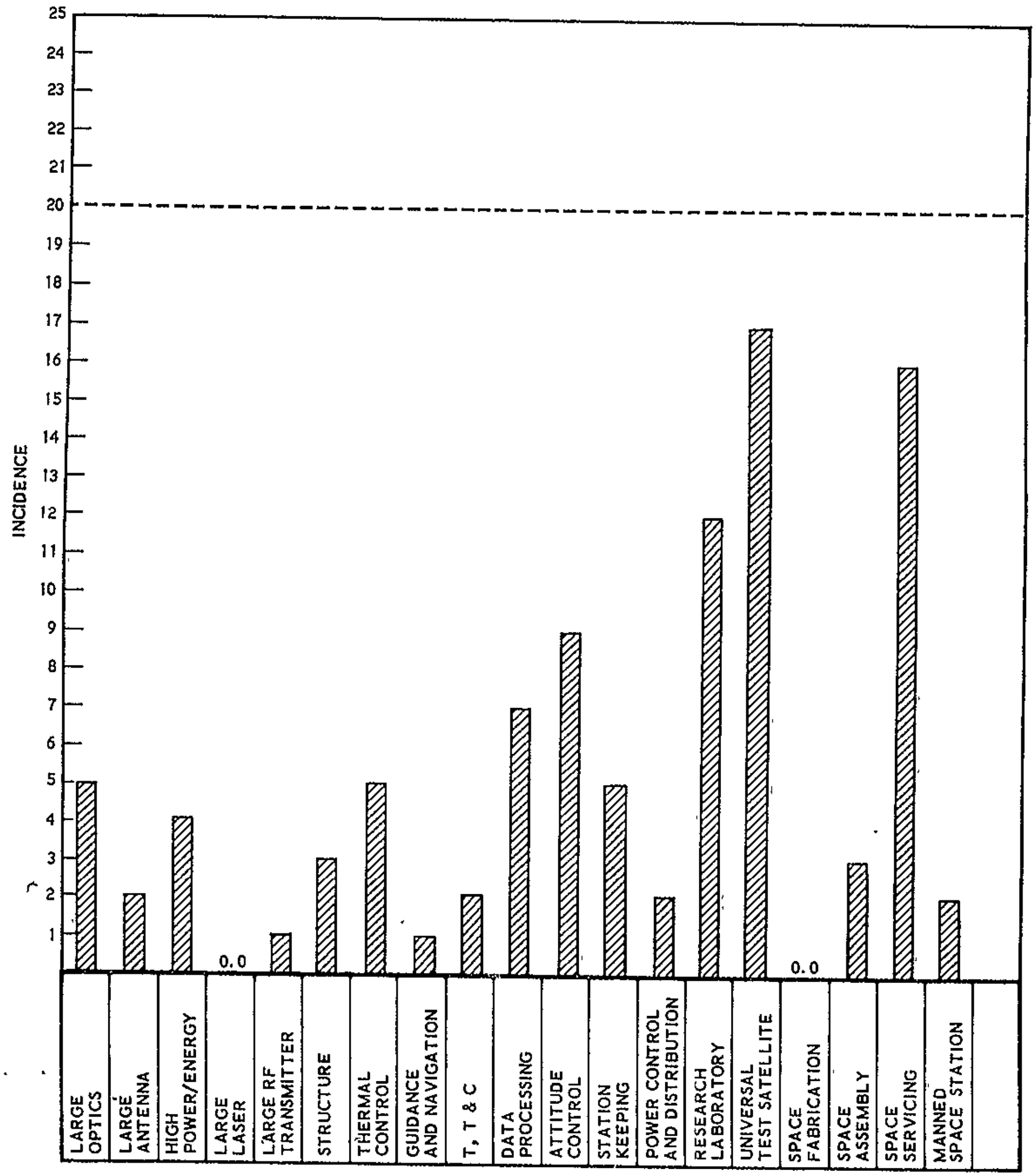
MILITARY OBSERVATIONS



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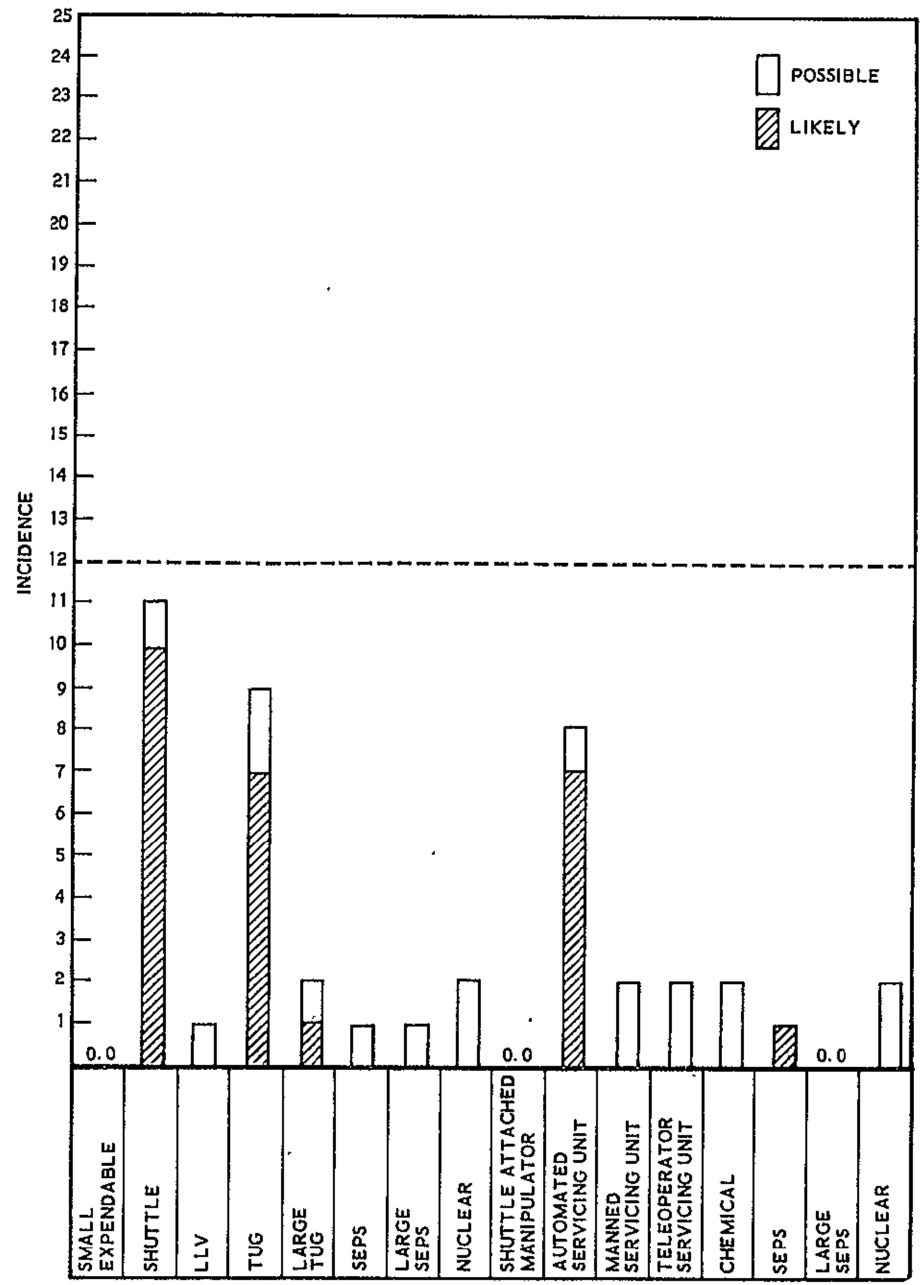
MILITARY COMMUNICATIONS



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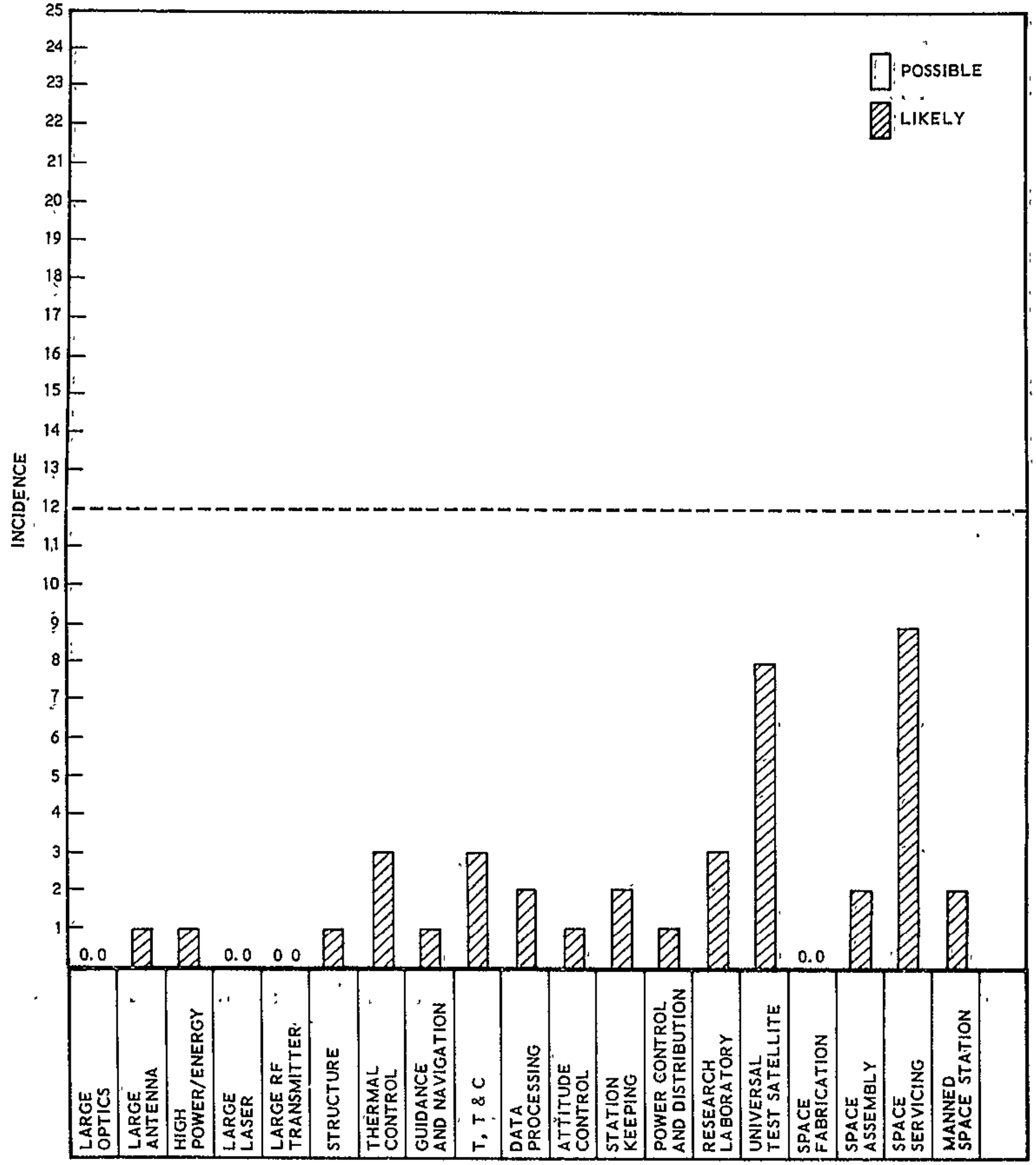
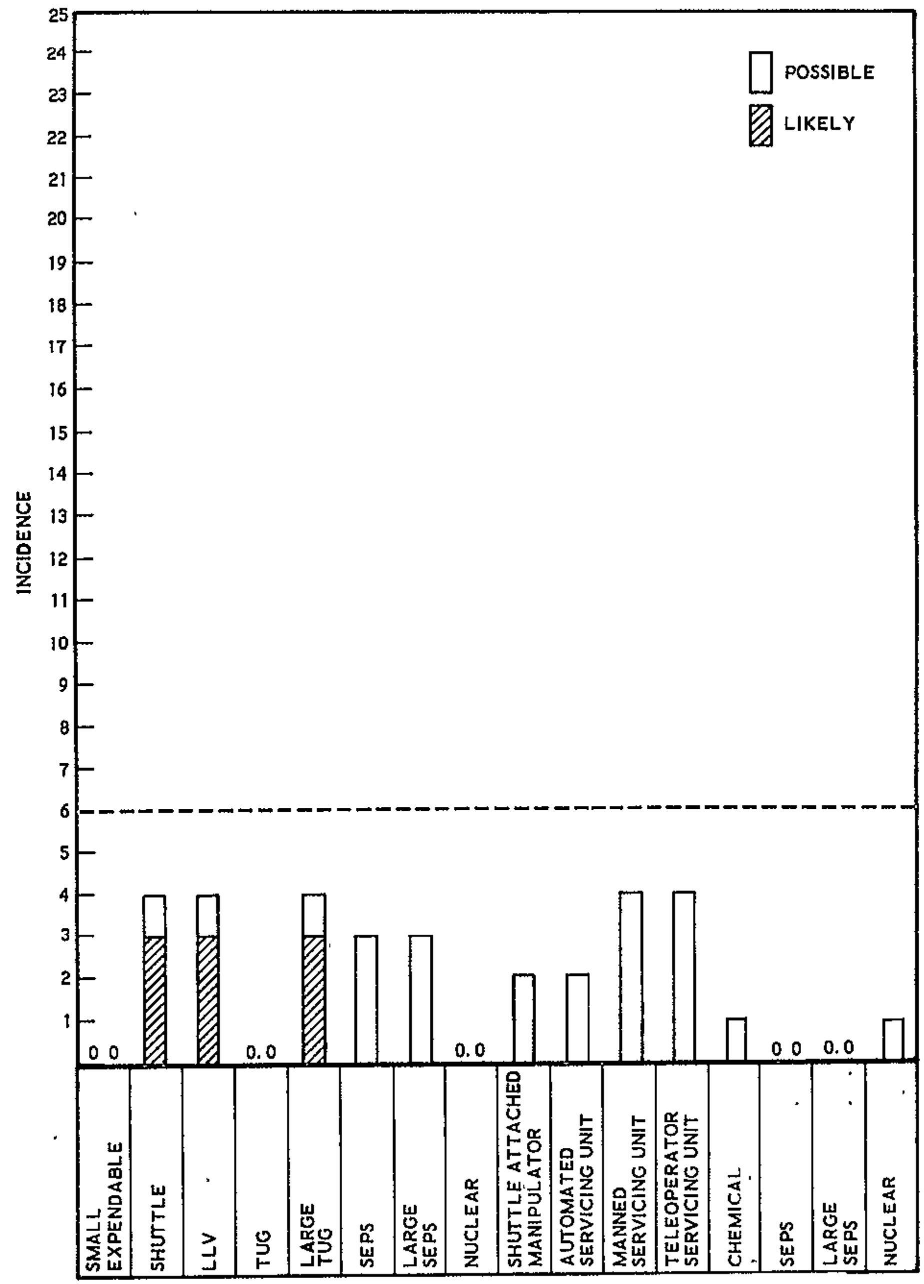
MILITARY COMMUNICATIONS



Building Block Requirements
MILITARY WEAPONRY



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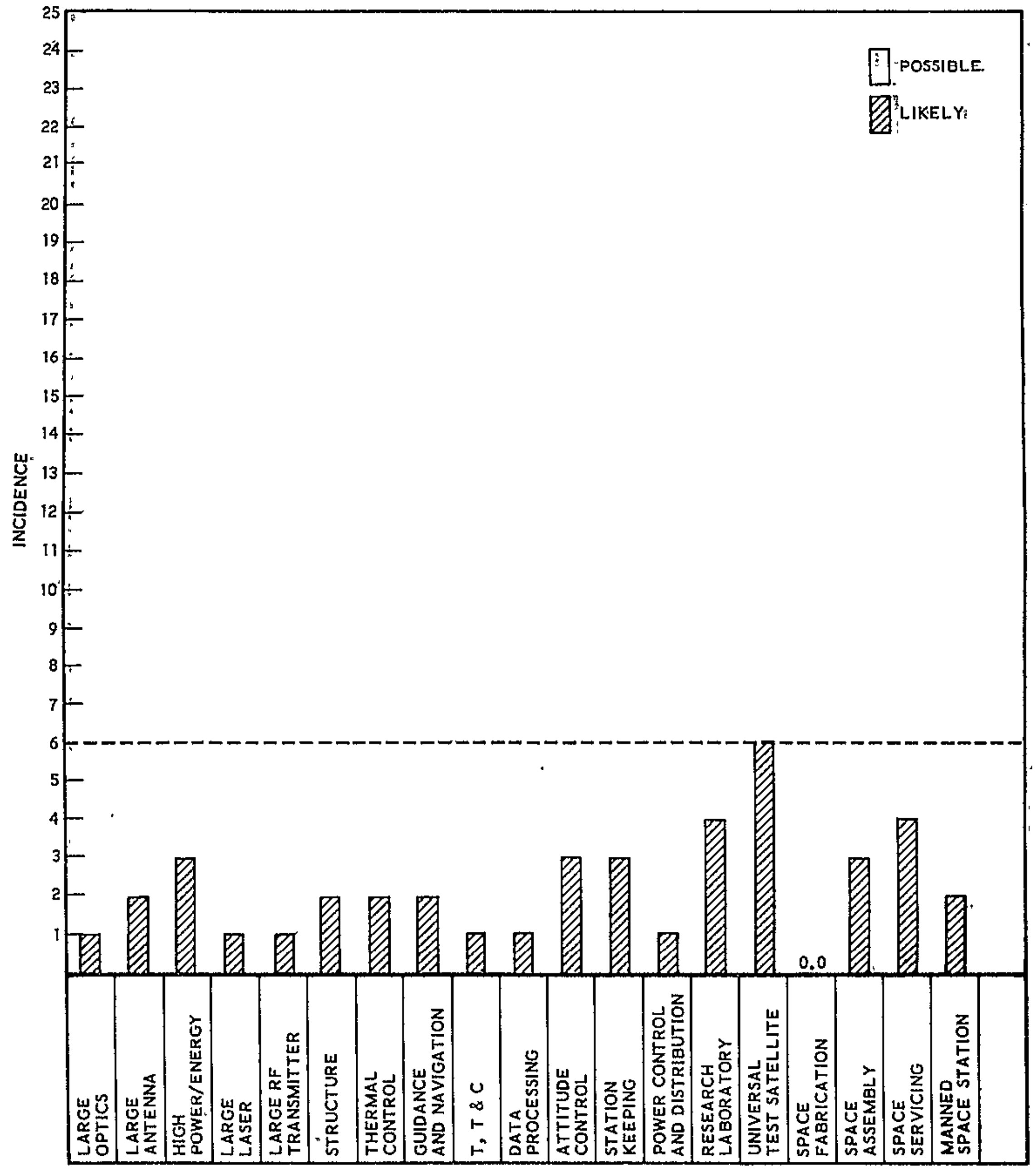
MILITARY WEAPONRY



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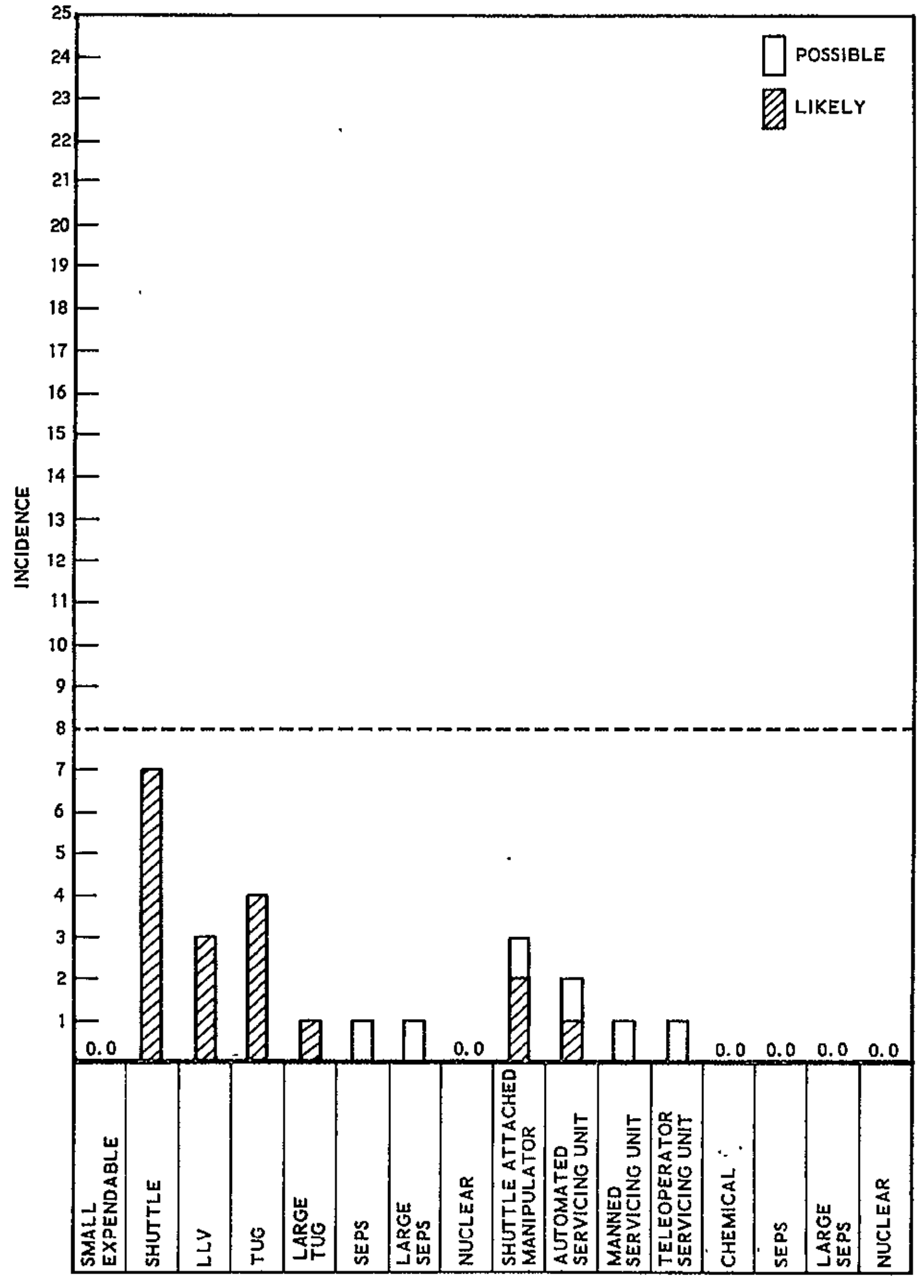
MILITARY SUPPORT



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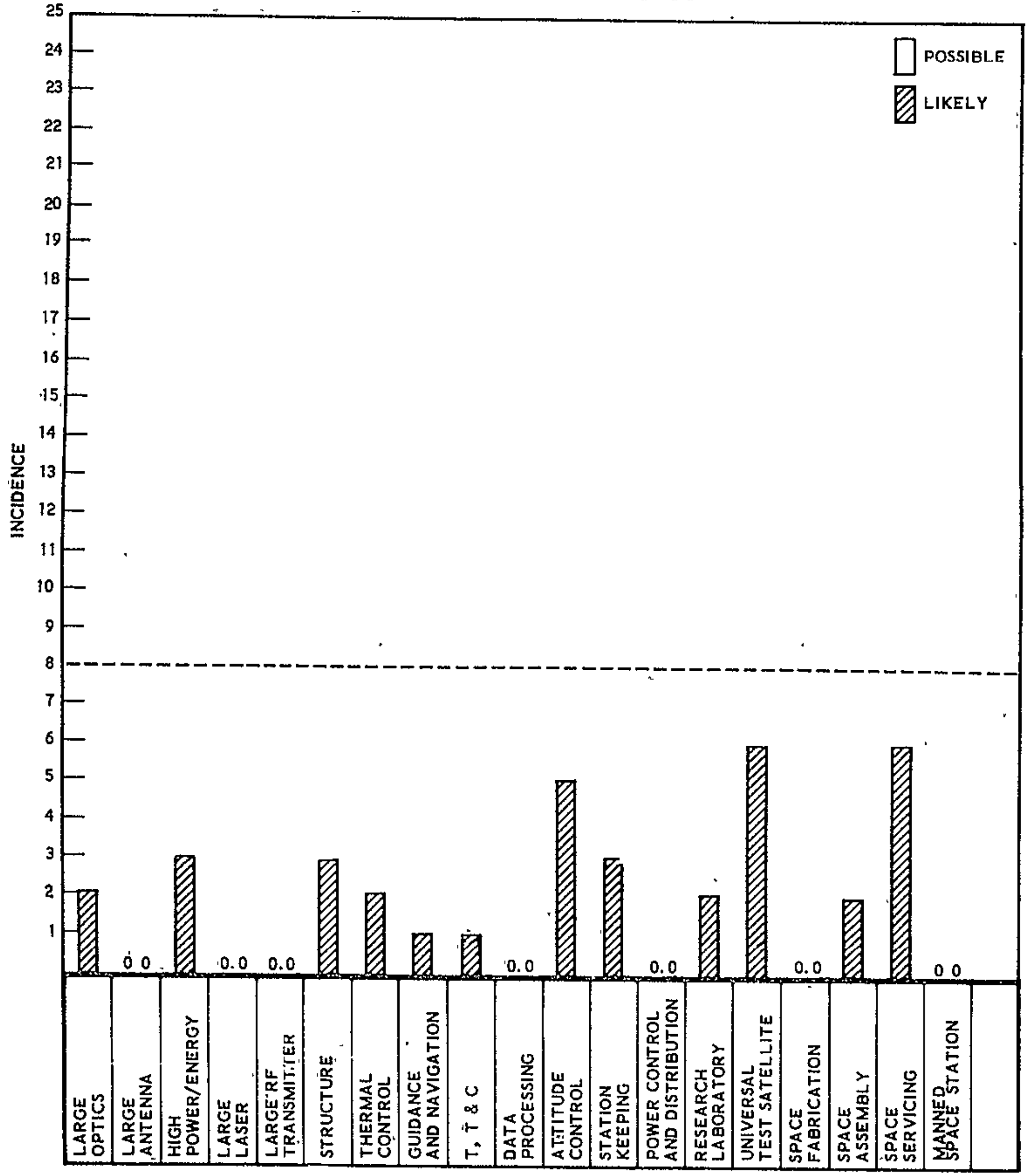
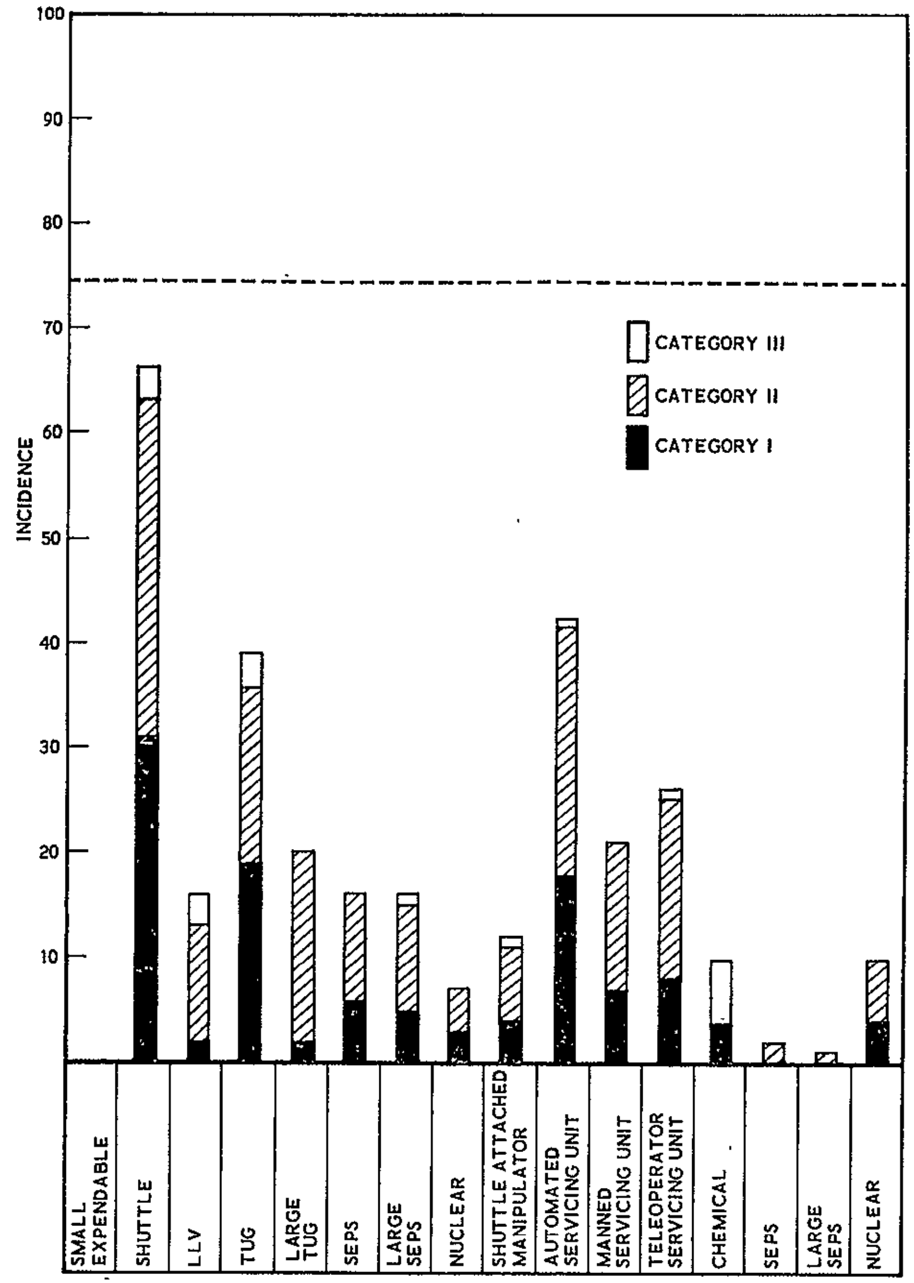
MILITARY SUPPORT

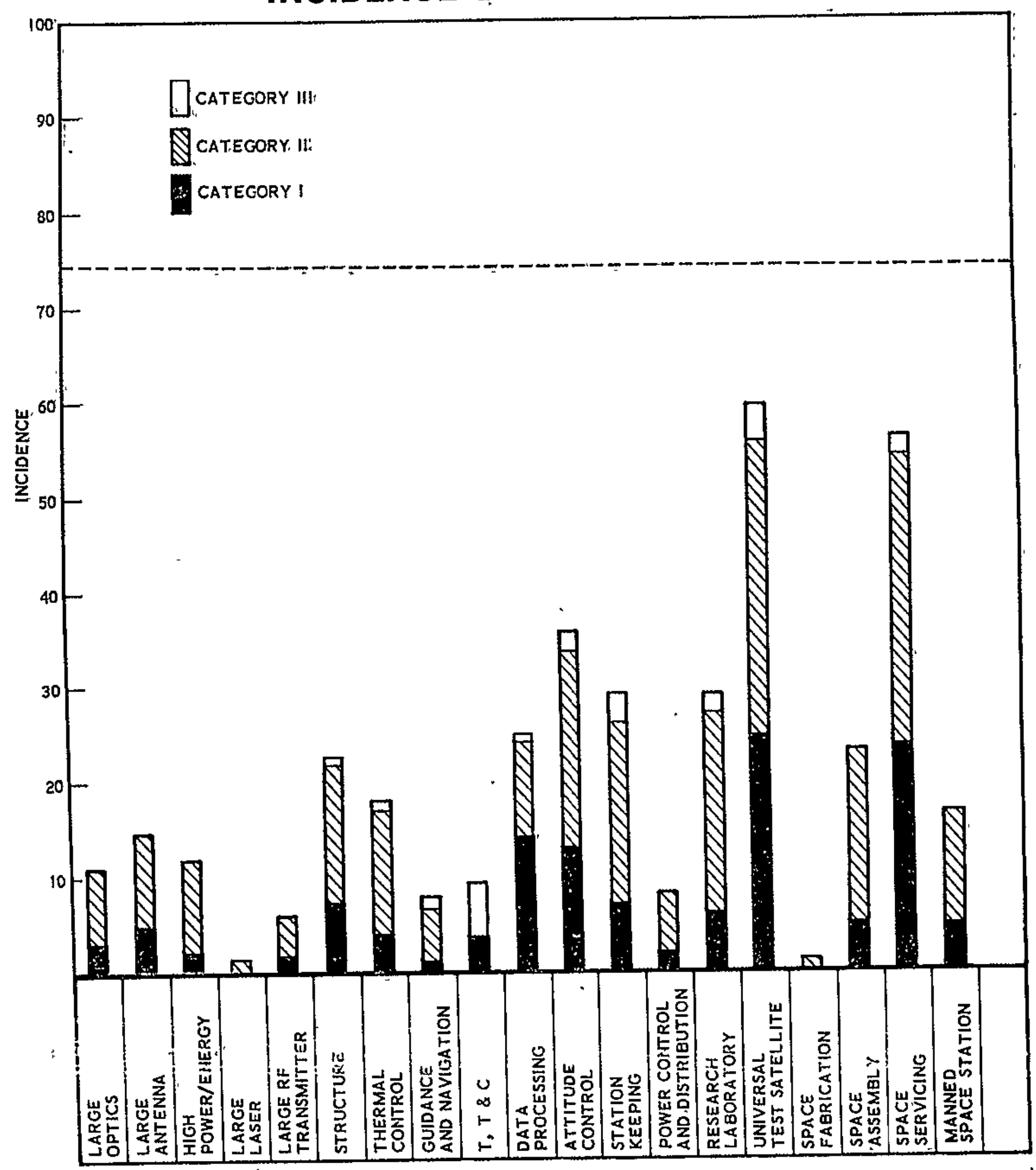


Building Block Requirements

INCIDENCE BY CATEGORIES



Technology Requirements
INCIDENCE BY CATEGORIES



E-1621

The next two pages combine the military and civilian initiatives performing the function of observation, so that some idea can be generated of the commonality expressed in the requirements by the initiatives in this class.

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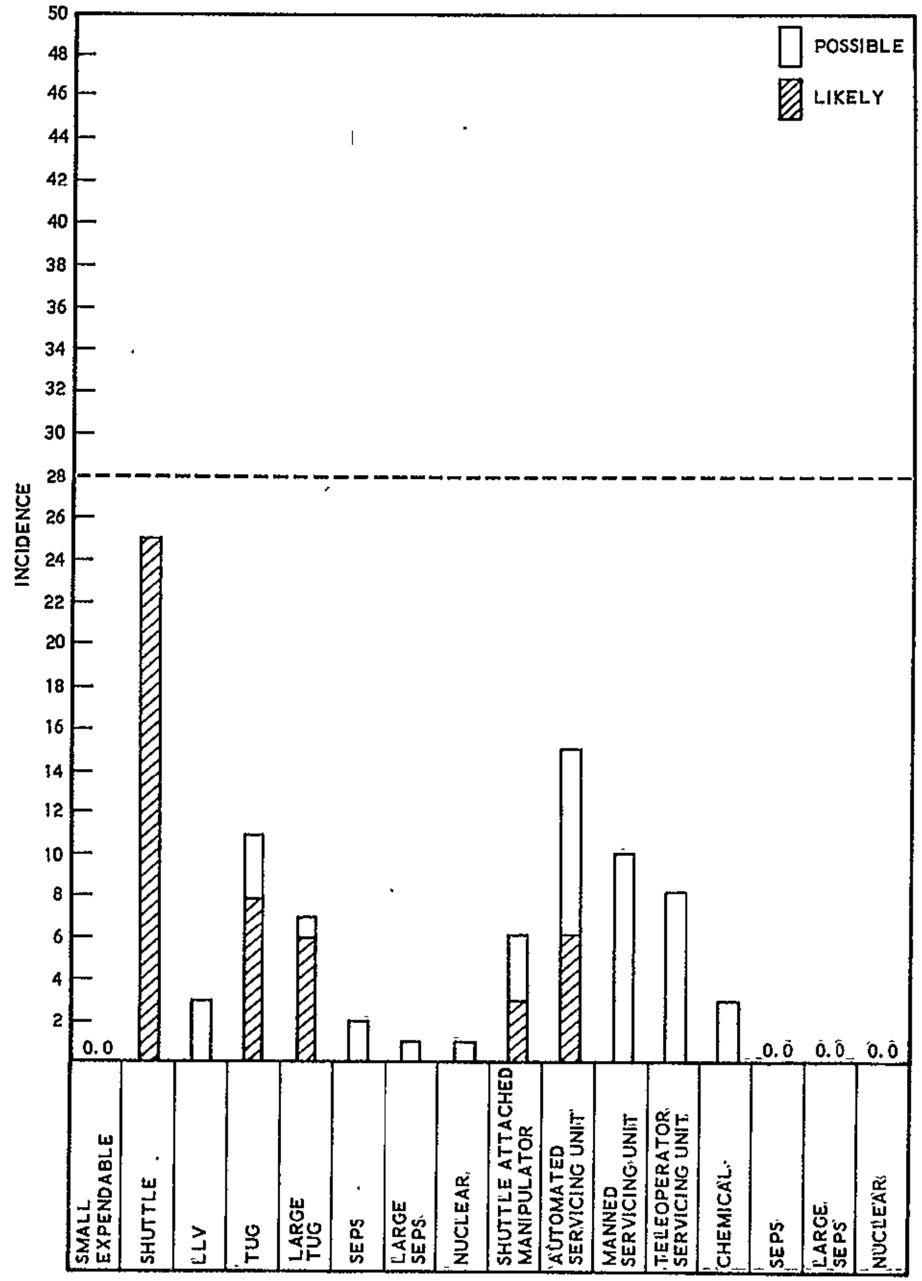
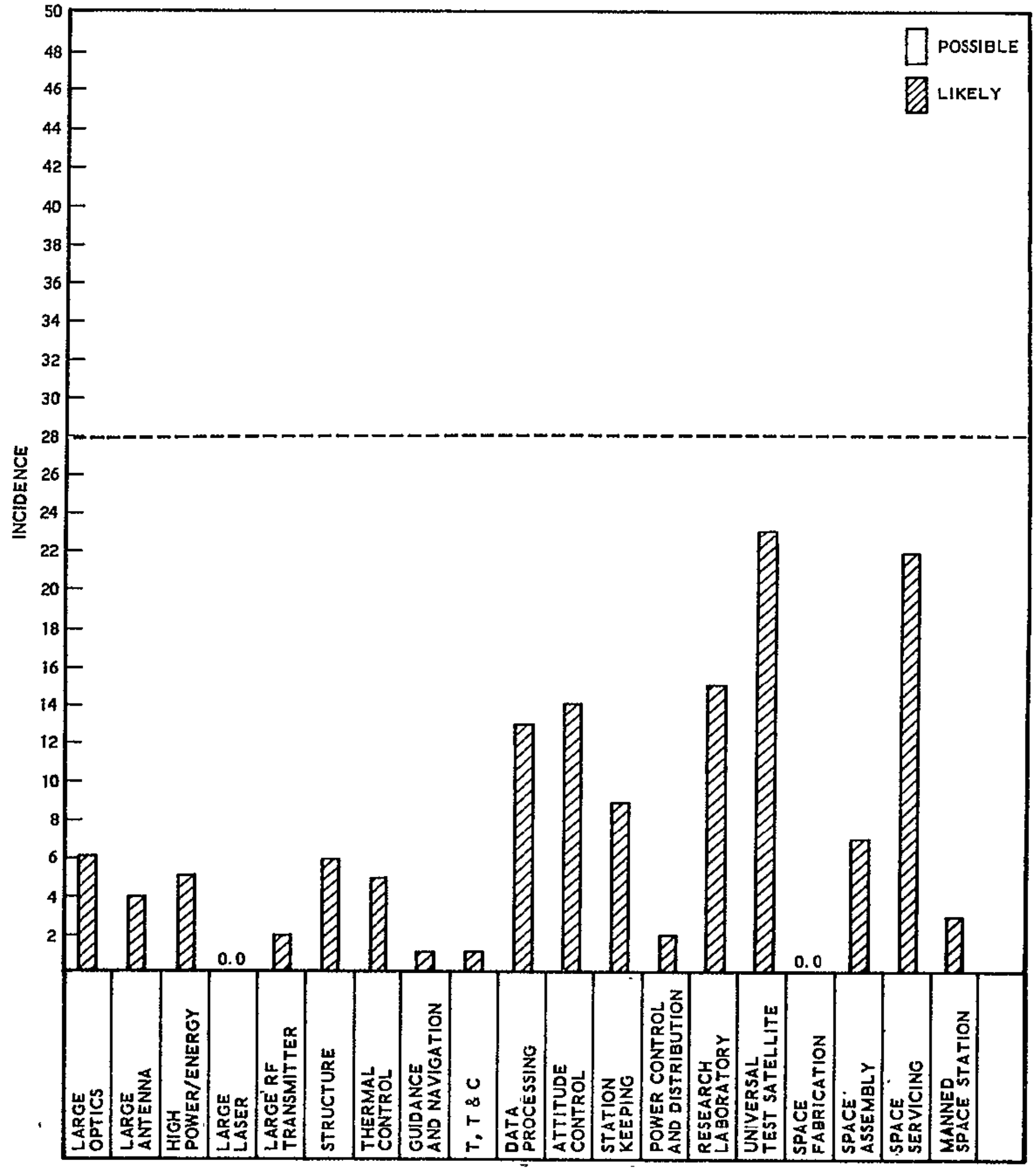
Building Block Requirements
MILITARY AND CIVILIAN OBSERVATION



Technology Requirements
MILITARY AND CIVILIAN OBSERVATION



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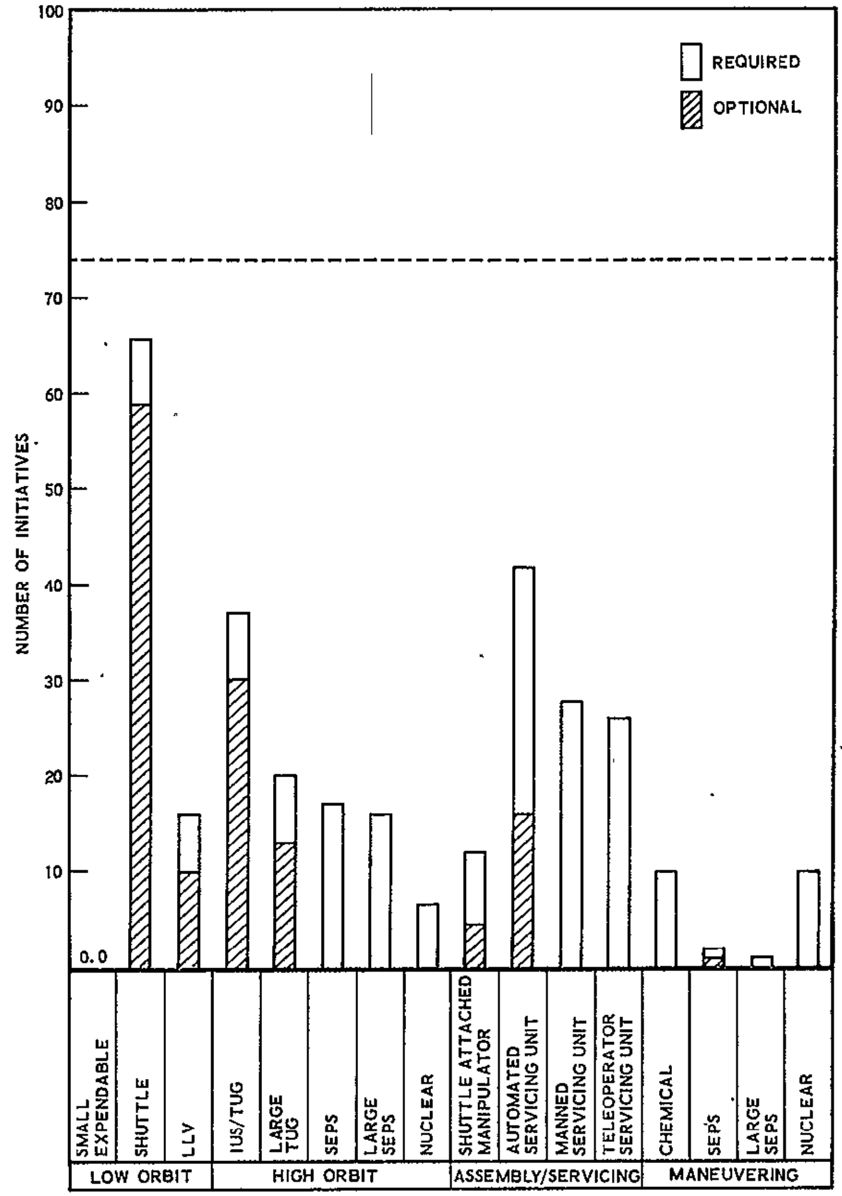
This page summarizes the building block requirements for all the initiatives in the catalogue. It is seen that the Shuttle and Tug are required by a large percentage of all the initiatives identified, with the large launch vehicle being required in about ten percent of them. The choice between candidates for the upper stages and servicing units is not at all clear, but it is clear that either a Large Tug, a SEPS or a Large SEPS appears to be required in at least half of the initiatives, and that some sort of a servicing unit, whether it be automated, manned, or teleoperator also appears to be required in about half of the initiatives.

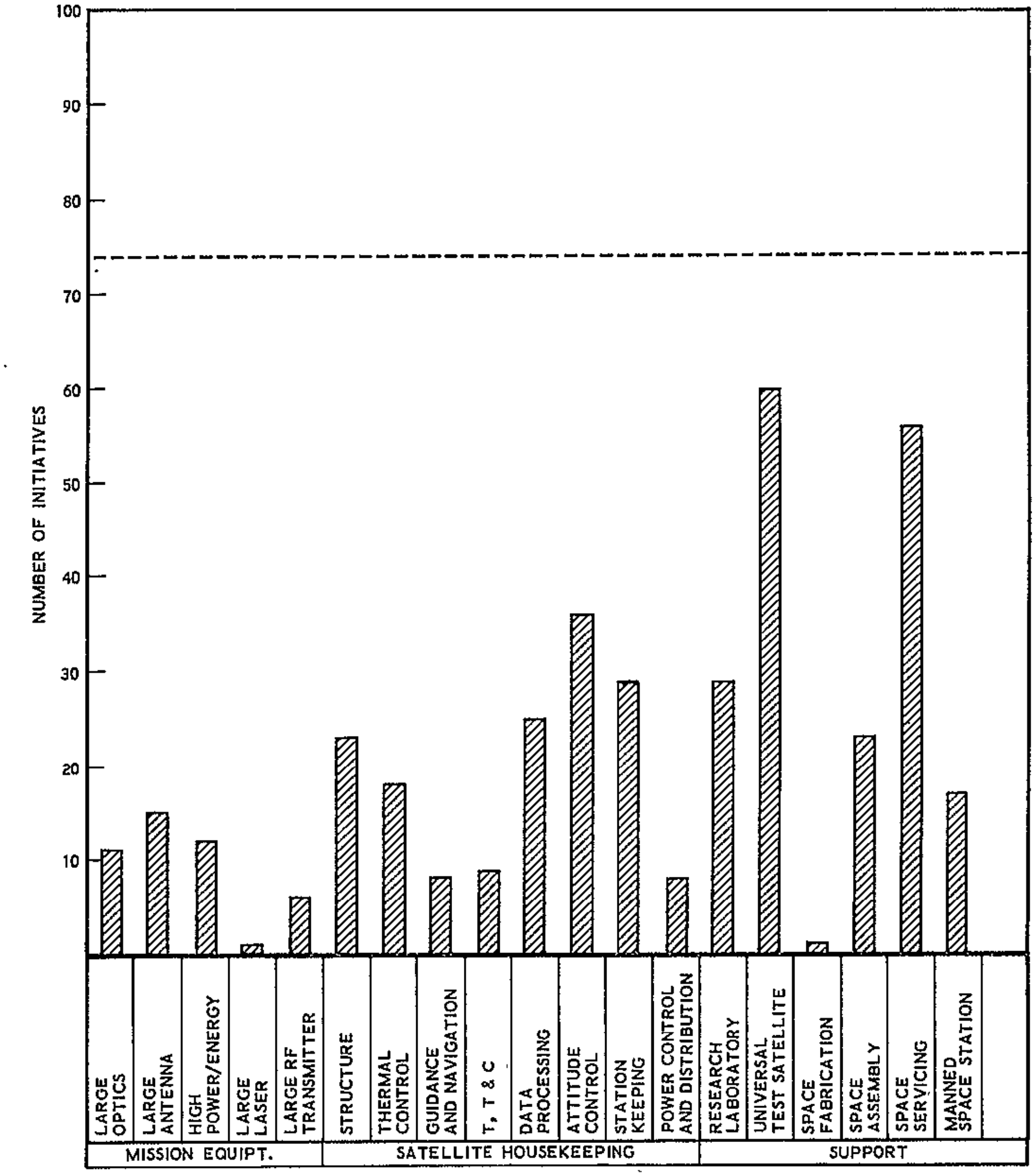
Building Block Requirements
ALL INITIATIVES



(U) This page summarizes the technology requirements for all initiatives in the catalogue. Only those requirements which are unusual or cannot be met by today's technology are identified in this graph. Space servicing and space assembly, structures, thermal control, attitude control, and stationkeeping loom large as technology requirements needed by a large percentage of the initiatives. The use of a research laboratory and of universal test satellites is also shown to be advantageous. High power, large optics, and large antennas, along with attendant power control and distribution problems, are shown to be required in about a quarter of the initiatives. The numerical values associated with some of these technological requirements are shown in Vugraph E-0976.

(U) The initiatives requiring space assembly include most of the large structures, most of which either require or would greatly benefit from manned assembly as well as manned initialization of functions. The servicing likewise could benefit from manned attendance at any altitude. Space fabrication of the very large but relatively flimsy structures from more dense stock which is matched in density to that of the Shuttle bay may also benefit from manned attendance. Some of the manned operations would be performed by teleoperator, though it may be advantageous to have man in space for the more complex tasks. A number of initiatives clearly benefit from the presence of man then, either in assembly, initialization, or servicing; and some even in the operation phases. Therefore, a requirement for a building block of some sort of a habitat or space station is implicit in order to house the crews to perform these functions.

Technology Requirements
ALL INITIATIVES



A number of observations can be made at this stage of the study: As evident by the large number and scope of the initiatives in the catalog, the advances which are possible in technology by the year 2000 could permit the fielding of many far-reaching initiatives, as well as numerous initiatives requiring a more modest growth in technology. These initiatives could have great impact both in the military and civilian areas, and show a great deal of relevance to the goals and functional requirements identified in the early part of the study.

In the civilian area, many initiatives have been identified which clearly could contribute towards solution of the many great problems facing the U. S. No single program of the emotional impact of the Apollo program has been identified, though a number of initiatives taken in combination could have a significant and lasting impact on the U. S. society. The civil initiatives show a complete correspondence to the functional requirements identified earlier in this study. Even though the most important initiatives in terms of their potential impact both in the military and the civilian area are those which are labeled "far-term", meaning that the research and technology base would probably not allow their fielding in an operational sense prior to the 1990s, the technology demonstration and phased testing of many of these initiatives could materially contribute to the makeup of near-term program plans, and would not require commitments to field such large programs a-priori. Many of the far-term initiatives identify directions for research and technology programs which could lead the technological community along those directions which appear to have great payoff in the future.

It is clear that man must be present and will have a role in many of the initiatives which appear to be of great impact. In the very large space structures which appear in many initiatives, man's role appears vital in initial fabrication, assembly, and reconfiguration of the structures, antennas, optics, and complex systems. He must be in space and present on the job in order to do this. Although the maintenance and repair function could be performed by automated servicing units, and though no tradeoffs have been performed, the complexities of the task are very large and man's flexibility and adaptability will probably be required in space for servicing. Though there are few initiatives identified which require a man to be in space and operate the space system, there are many in which he must be in the loop, but he could very well be in the loop as a

OBSERVATIONS

- GREAT ADVANCES ARE POSSIBLE IN TECHNOLOGY, PARTICULARLY IN VERY LARGE OPTICS, ANTENNAS, LASERS, DETECTORS, AND LSI PROCESSORS
- THESE TECHNOLOGIES WILL ENABLE FAR-REACHING INITIATIVES, IN ADDITION TO STRAIGHT-FORWARD EXTRAPOLATION OF CURRENT PROGRAMS
- FAR-TERM MILITARY INITIATIVES HAVE BEEN IDENTIFIED WHICH COULD MATERIALLY ALTER THE STRATEGIC AND TACTICAL BALANCE OF POWER
- FAR-TERM CIVILIAN INITIATIVES HAVE BEEN IDENTIFIED WHICH COULD MAKE SPACE RELEVANT TO THE COMMON MAN-IN-THE-STREET, AND WHICH COULD CONTRIBUTE MATERIALLY TOWARD SOLUTION OF MANY OF THE PROBLEMS FACING THE U. S.
- PROGRAMS OF TECHNOLOGY, DEMONSTRATION, AND PHASED TESTING OF MANY OF THESE CAPABILITIES COULD CONTRIBUTE SUBSTANTIALLY TO THE MAKEUP OF NEAR-TERM PROGRAM PLANS
- ROLE OF MAN APPEARS VITAL
  - IN FABRICATION, ASSEMBLY, MAINTENANCE, AND RECONFIGURATION OF VERY LARGE STRUCTURES AND ASSEMBLIES IN SPACE
  - AS TELEOPERATOR, LOCATED IN SPACE OR ON THE GROUND
- GREAT COMMONALITY IS EVIDENT IN THE TECHNOLOGY AND BUILDING BLOCKS TO SUPPORT THE NASA AND DOD INITIATIVES

teleoperator located on the ground. Man's role in the first instance has implicit requirements for some sort of long-term habitat in space to house the working crews. This fits in nicely with the eventual use of space for establishment of colonies which, though beyond the cut-off date of the year 2000 for this study, implies a requirement for space stations to perform research on long-term, closed-cycle environments. Thus dual-use could be made of the space stations which will be required before the year 2000, to assemble and service some of the large initiatives in this catalog, while performing inherently the research on long term closed cycle working environments.

There also appears to be a good deal of commonality in the technology and building blocks required to support many of the applications between the military and the civilian areas. This is true for the near-term as well as the far-term initiatives identified. Even though the detailed analysis of the commonalities will only be explored during the second half of this study, it is clear that many building blocks and technologies will be needed in common.

The remainder of the study will develop several alternative program plans matching several alternative scenarios of future needs, and then for each program plan, the specific technologies and building blocks required will be identified as a function of time. Those needed in common between NASA and DOD for each scenario will be discussed in more depth. Since some of the scenarios will utilize mainly near-term initiatives, they will surely represent lower risk statements of commonality, rather than commonality based on far-term initiatives called upon in scenarios which will be very optimistic about utilization of space. Both types of scenarios, and resulting commonalities, will be explored, as well as in-between cases. At the end of the program, common building blocks and technologies needed will be relatable to the choice of scenario desired. Methodologies will also be presented to allow such choices to be made by anyone wishing to construct scenarios other than those in the report.

PROGRAM PLAN FOR REMAINDER OF FY 75

- COMPLETE ALTERNATE ENVIRONMENTS/SCENARIOS
- DEVELOP METHODOLOGY FOR CHOOSING INITIATIVES FOR ALTERNATE PROGRAMS
- LAY OUT ALTERNATIVE PLANS; EXTRACT BUILDING BLOCK AND TECHNOLOGY REQUIREMENTS FOR EACH PLAN
- DETERMINE COMMONALITY FEATURES IN EACH PLAN

APPENDIX A

FUTURE ENVIRONMENTS, GOALS, AND SPACE FUNCTIONAL REQUIREMENTS

APPENDIX A

FUTURE ENVIRONMENTS, GOALS, AND SPACE FUNCTIONAL REQUIREMENTS

This appendix presents the work done to date on determination of the functional requirements which could be placed on space systems by the environments likely to exist in the period 1980-2000. A "most likely" forecast is made for both the civilian and military environments, and presented herein. Variations will also be derived, both more optimistic and more pessimistic than that presented in this appendix, and submitted in the course of the next phase of the activity.

This appendix is divided into two sections, the first of which addresses the civilian and the second the military environments, goals, and space functional requirements.

FUTURE ENVIRONMENTS, GOALS AND SPACE FUNCTIONAL REQUIREMENTS

CIVILIAN AREA

C 3

INTRODUCTION

1. PURPOSE

As a basis for planning for the 1980-2000 period, we should have a reasonable set of goals for the civilian space program of the country. Three intertwined questions are involved in determining these goals -- what the country really needs, what the country desires to have, and what technology and nature are capable of delivering. This appendix attempts to make some contribution towards answering the first two of these questions. The technology potentials were discussed to some extent in the body of the paper.

2. METHOD OF FUTURE HISTORIES

If we had the benefit of hindsight and could look from the vantage point of knowledge of the state of the world in the year 2000, we could construct a reasonable set of goals. Therefore, we have used the method of creating a synthetic future, and then employed our hindsight on it. This synthetic future is the main subject of this appendix.

In creating this future, we have predicted both general trends and a general pattern of events. The general trends were chosen because we believe that they have high probability of occurrence. The events, however, were chosen to give a concrete realism to our view of the future, and not because they necessarily have high probability of occurrence in their specific form. Our method is thus a combination of the historical scenarios approach and trend discernment. In a pure scenarios approach, a variety of scenarios would be examined and appropriate goals for the civil space program would be constructed for each one. Goals common to many scenarios would then be selected as having general validity and high probability of being reasonable goals for the future. The variety of scenarios was not explicitly constructed in our study, although they were implicitly considered. The trend discernment is in part some blurred statistical consideration of probable scenarios.

Future trends and scenarios always evoke more controversy than consensus, and our predictions will not be exceptions. But the use to be made of the predictions should be considered before fully fueling the heat of controversy. We have the limited aim of determining goals for the U.S.

civil space programs, rather than the general aim of planning for the whole future of society. Specific predictions and even some trends serve their purpose for our ends in forcing us to be concrete and realistic in selecting goals, instead of merely relying on general principles.

3. CATEGORIES

In our description of the future, we distinguish the following categories:

1. Political
2. Economic
3. Technological
4. Cultural
5. Institutional
6. Intellectual
7. Emotional
8. Spiritual

For this appendix only the first four categories have been considered in detail, but the last four had been kept in mind in the selection of goals for the body of this report. In each category, although a broad range of topics is discussed, a partial pre-selection has been made emphasizing those subjects which directly affect the space program or the willingness of the country to accept it.

POLITICAL

1. GENERAL

The continuation of the American system of federal government in essentially unchanged outward form seems the most reasonable prediction through the year 2000 at least. This prediction is not just an expression of hope, but a realistic evaluation of potential changes. The outward form of the American system permits, and indeed encourages, changes in the actual responsibilities and functions of government sufficient to adapt the system to the changes of the future world. Therefore, the U. S. political democracy exercised through a representative republican governmental form under an established constitution and system of statutory laws should persist, but the roles of institutions will be changed, as will the customs and the accepted modes of governmental action.

Whatever the specific form, a greater and more intimate interaction between the individual and the federal government is expected, with government being more responsive to individual needs, and individuals more critically affected by many government actions. The space program in particular will exhibit this interaction to an unusually high degree.

2. THE PARTY SYSTEM

Basically the two party system should continue, and the party system itself should continue to play its role of channeling political activity. The following elements in a future scenario are presented as a concrete and reasonable possibility, but by no means a unique prediction for the future. However, the central conclusion drawn from this scenario will be independent of its details.

2.1 Republican Party

This party will contract in size and become more homogeneous in political philosophy -- really coming to represent big business and conservative interests.

2.2 Democratic Party

This party will be "babelized" as it takes up groups of all shades of political philosophy from right to left, and many special interest

groups. Party policy will be changeable as labile coalitions form and break up.

2.3 Other Parties

There will be a succession of "third parties" as political crises dictate or opportunity provides, mostly of populist orientation. Also there will be perrenial "crank" parties, with total strength growing to between 5 and 10% of the population. These parties will be based upon a single emotional issue (as for example the prohibitionists today). In some local governments the crank parties may actually hold the balance of power.

2.4 Demagogues

A succession of demagogues is foreseen -- most quite unbelievable. But the perceived threat to traditionalism will be exaggerated compared to their real threat, and the demagogues will exert an exaggerated negative influence on the direction of the policies they espouse.

2.5 Tentative Conclusion

Whether the above specific predictions materialize or not, we feel that the 1980-2000 era will see a very much more complicated internal and external picture in party politics. The party struggles will tend to interfere with orderly and rational progress in government, more particularly at local and state levels. In state legislatures, the fraction of seriously considered legislative proposals that are enacted into law will decrease markedly. In the federal government, this fraction which is already very low, will decrease somewhat more. Such muddling will result in an erosion of confidence of the public in the legislative branches of the government, and in the party system. Little effect is seem, however, on the confidence in the executive and judicial branches.

3. ROLE OF THE PRESIDENCY

3.1 An Institutionalized Presidency

The presidency becomes well institutionalized with a structure established by legislation. The institution will resemble, to a considerable extent, a military general staff, with loyalty to the President and obedience in carrying out orders equally important to wisdom in planning or in establishing policies.

The institution of the presidency will have a life of its own, abstracted from that of the President himself. Changes in the personality of the President, and even of the party of the President, will have a diminished effect on executive policies. In some administrations the President could be a ceremonial figure, in others a planning force, in others a management center, and in others a political power, but the presidency itself will operate to a considerable extent unchanged by the specific capabilities or interests of the President.

3.2 Computer Programs as Power Sources for Presidency

The presidential staff will have complicated computer simulation programs and data processing programs as planning and administrative aids. These programs will persist from administration to administration and provide a continuity of capability despite personnel changes. Many decisions will be fore-ordained by the nature of these programs -- or by the lack of them. Particularly significant will be the programs concerning the budget, since no governmental department will have as far-reaching a capability as the presidency in the overall budget. Complete new budgets in every detail will be producible by computer program within one hour, and variations on the budget will be routinely used to arrive at staff decisions. Budget analysis and synthesis routines will be so well developed, that program content and interrelations of programs will be apparent to the presidency whenever its interest is sufficiently aroused to raise the question. Presidential supervision of the executive branch will increase and independence of the governmental departments, particularly the DOD, will decrease.

3.3 The Constituency of the Presidency

The President will utilize a national constituency on a continuing basis. By mass communication, he will advocate programs and policies. By opinion sampling techniques he will be responsive to public reactions. The presidency, more than the Congress, will be responsive to individual public opinion, and the President will use this public support to influence the Congress. (Special interest groups and local constituency will directly influence individual congressmen and senators in local matters, but will not have a strong influence on the President.)

The presidency will have a specific parochial interest in space programs which give it the technology to communicate with and sam-

ple its constituency. But the space program will not be considered as a vehicle for popularizing the President.

3.4 Presidential vs. Congressional Initiatives

In this area, future history will have branch points depending on the relative strengths of the institutions of the presidency and of congress (but not so much on the strengths and personalities of the individuals in the institutions.) Some generalities, however, may be invarient.

The President will be innovative in specific issues and on minor policies, and the congress will follow the presidential lead in them. For example, an international program for a cooperative communications satellite network could be instituted by the President, and Congress will ratify the program by providing funds without searching questions on policy. However, it will be Congress, not the President which will decide major policy matters -- such as the decision to embark on a development program leading to space colonization.

3.5 Long Range Planning by the Presidency

Currently administration policies are focused on payoffs within the administration lifetime, 4 to 8 years. This focus will remain. But more and more the presidency will use computer models to test effects of policy decisions. The models will in fact be capable of aiding plans beyond the 8 year horizon, because the model builders will be professionally motivated to make their codes so competent. The President, therefore, will have predictions on long range effects, and, on many occasions, he will champion programs on the basis of 10-20 year accomplishments. In the complicated era of the 1980-1990, a President may have difficulties in getting public sympathies for short range programs that, while needed, will be disagreeable, and the President may therefore appeal to long range programs which can give a charisma to his office. Bold space programs will be of that nature. As a soft conclusion, we feel that short range space programs to be supported by the President will need economic or social service justification, but long range programs can be visionary and appeal to some emotion about the ultimate destiny of the human race.

4. ROLE OF CONGRESS

4.1 Constituency

The individual citizens in each district will become the most important constituency of Representatives and Senators. The congressmen will have increased access to their constituents through mass communications. They will have increased responsiveness through extended use of sample polls, and possibly fairly large scale straw votes. Election campaign reforms will lessen the dependence of congressmen on money contributions from organized labor and business, and will reduce the influence of these groups on congressional policies.

4.2 Information Flow to the Public

Congress as a body, and individual congressmen, will become very important agencies in getting information from the executive (and to a small extent the judicial) branch of the government to the general public. The government will become more public service oriented so it will have more information of direct value to the public. The political power of consumerism will be an effective mover in getting this information out of the government. The space program in particular will operate in a "goldfish" bowl in the future, as in the past.

4.3 Data Management in Congress

Congress will adapt computer data processing aids in many areas, but particularly in its budget work. Much more detailed and extensive data is therefore going to be requested by Congress from the executive branch. The executive, of course, will also use extensive data processing routines. To some extent and in some spirit, the information relation between Congress and the executive will be by computers talking to each other.

In the complicated world of the future, information control will mean power, and the computer evolution will mean a more even distribution of information between the executive and the Congress and a shift in the power derived from control from the executive to Congress.

Congress in the future will develop measures of effectiveness for policies and programs -- with the aid of computer data processing they will monitor effectiveness. Future appropriations will depend upon

effectiveness to some extent, although public acceptance of performance will still be the guiding principle, and that will still be emotional.

4.4 Long Range Planning and Advanced Programs in Congress

Society will face large new problems in adjusting to the complicated world of the late 20th century, and Congress will have to provide many new legislative initiatives in an effort to solve them. There will be new landmark legislation comparable in kind but much greater in the magnitude of their effects to the atomic energy and space agency legislation of the middle century.

As in the case of the presidency, computer modeling under Congressional auspices will be used as a tool for testing legislative proposals, and long range planning will have a significant impact on legislation.

4.5 Space Legislation

Congress will balance the needs of the country, formulate the advanced space plans and set up appropriate agencies for their execution. In discussing future legislation, however, no well designated roadway is apparent, and so a variety of branch paths will be suggested. The following are some of the possible branches.

(1) Commercial Exploitation of Space

A NASA like organization will be maintained for research and exploratory development of space equipment and of advanced ideas for space exploitation. But the major exploitation will be by commercial corporations -- communications corporations for communication links, TV broadcasts, computer data links; industrial corporations for earth resources information; DOD for military applications but via its defense contractors, etc.

A second regulatory body analogous to FAA will see that, in the public interest, proper standards of safety and performance are attained.

(2) Common Carrier

NASA will have a common carrier role in space, putting aloft and maintaining all payloads, and providing ground services. However, NASA will not be responsible for the performance of the payloads, and will have only a small veto role in selecting them.

(3) NASA as R&D Arm of DOT

NASA will be attached to the Department of Transportation. It will have enlarged responsibilities as the research and development arm of this agency, and will become involved in ground transportation as well as air and space transport, although the latter will then be deemphasized. Considerable emphasis will be placed upon space activities as a support to ground transportation systems. Space exploration will be transferred to the National Science Foundation.

ECONOMIC

1. THE LABOR FORCE

1.1 Numbers

The number of people in the U.S. working force will increase over the current level at a faster rate than the population increase. This increase will be due to the population age distribution, with more young persons moving into the employable years than old people moving out, and to the influx of a larger proportion of women into the working force.

1.2 Hours of Employment

A well based prediction for a decrease in mean working hours cannot really be made. There are forces tending towards a shorter nominal working week, for example by craft unions, but very often the shorter hours are supplemented by overtime at increased rates, so that the actual average work week remains unchanged. Furthermore, if shorter working hours become the rule in the future, we expect more "moonlighting" by individuals, and more personal business carried out in spare time. The actual contribution of productive hours to the total economy per man may just as well remain unchanged as the nominal work week is reduced.

1.3 Level of Employment

Full employment will be accepted as an economic goal as well as a social need and political necessity. The U.S. will be involved in international economic competition and just will not be able to stand the loss in production due to low levels of employment. In one way or another, appropriate institutions will be developed to attain full employment most of the time. Small amplitude cycles of unemployment will, however, persist.

1.4 Labor Effectiveness

Labor effectiveness depends upon training and capital investment per man, and on motivation of the worker. Both pre-job training in our educational institutions and on the job training in industry will become better, particularly for jobs requiring a middle level of skill. Capital investment

per man will continue to increase exponentially. But motivation may be uncertain in the future. The U.S. culture is in a transition from a system of traditional small rewards largely internalized, to a system of large external rewards, and how this change will proceed is not known, although it is sure to be temporarily disturbing.

1.5 An Economy of Surplus

The labor base for an economy of surplus will certainly be available--a surplus larger than those we have already known. In the past, the times of surplus have been times of intellectual and spiritual progress, and this could be so in the future. Large space programs, with intellectual and spiritual payoffs, rather than economic return, are in principle possible in such an economy.

2. CAPITAL

2.1 Effectiveness of Capital

In new and high technology industry, capital investment pays off at a much higher than linear rate in productivity. We foresee a substantial portion (1/4 to 1/3) of U.S. industry in this category in the 1980-2000 period. In established industries, the payoff for capital investment appears to be almos linear at present in the U.S. But most industry is still undercapitalized, and in the future, rather than seeing the effects of diminishing returns, we predict a continued linear increase in productivity with capital investment.

2.2 Supply of Capital

Capital, of course, results from the excess of production over con sumption. The U.S. itself will continue to be the greatest source of capital per capita in the world, and a very large source in total. In the remainder of the industrialized world, we predict consumption to increase relative to production, particularly as the Soviet Union and Japan move away from strict austerity, and concentrate more on consumer goods production. The poorer one-third of the world will continue to consume at a level which matches or exceeds their own production, and will be a sink not a source of capital. The middle third of the world may go either way--accumulate or dissipate capital. Their net contribution to the supply will be small in any event.

2.3 The Capital Market

In the capital market, the future picture appears to be a disturbed one--the only sure prediction is that the market will be much more complicated than it is today. Internationally, there will be formidable barriers to the free flow of capital, and so the world will have a managed rather than a free market. China appears strong enough in political structure to keep its capital resources internally, and of course she has good use for it there. The same pattern is predicted for the Soviet Union.

A significant effect in capital distribution is caused by the cartel action of the petroleum producing states. Per year, the excess capital flow due to cartel action is about $50 billion, about comparable to the increase in GNP of the U.S. There will be some tendency to put this capital in exactly the same place as it would have gone anyway. The net result would then be a transfer of ownership, but no change in the pattern of production. On a worldwide scale, we predict little change, in fact; but on the local scale of the individual oil-producing states, the changes will be marked, as the wealth of these states increases.

Great capital resources will be in the hands of governments, and governments can make their own capital distributions dependent upon political and social aims, not only economic returns. In the U.S., local, state, and national taxes amount to about one-half the GNP, and the resulting concentration of capital is larger than that of any other source. We predict that wise manipulation of this capital will stabilize the entire capital market, smooth out effects of business cycles, and provide needed balance between long range goals and immediate needs.

2.4 Level of Capital Investment in the U.S.

We foresee an adequate supply of capital provided by surplus production, an incentive for its investment because of its effectiveness in increasing production in the U.S., and a confused market, stabilized by government actions, to direct the flow of capital into productive or socially desirable channels. Capital as well as labor, then, will play its role in the U.S. in producing an economy of plenty.

3. RESOURCES

3.1 Energy

Basic energy supplies for the U.S. and the world are good for the 1980-2000 period, and there is hope in technology for rich energy sources for the conceivable future. But there are current problems in energy distribution and in the forms of energy readily available. This discussion will be focused on the U.S. energy position.

The U.S. is richly endowed with coal, so richly in fact that our coal could supply our energy needs for hundreds of years. The coal industry, however, has been neglected in the last 20 years due to the availability of inexpensive domestic natural gas and plentiful supplies of cheap foreign oil. Our reserves of natural gas are now small, and they can furnish only a minor contribution to our energy supply between 1980 and 2000. Oil and coal will be our major sources for basic energy during this period. At present there is restricted interchangeability in their use. But technological developments on a ten-year time scale will enhance this interchangeability. Large stationary plants can be converted rather readily from oil to coal with proper attention to cleaning up stack wastes. Small heating plants for home and office space heating cannot so easily be converted, and the hope here lies in coal gasification. We predict a vigorous and economically successful program of coal gasification leading to interchangeability of coal for oil at the oil price of about $6 per barrel (1975 values) by 1985. Thereafter the price of gas from coal in terms of man hours U.S. labor equivalents should drop steadily, as the entire coal industry is modernized and gasification is simplified.

Oil is truly scarce compared to coal or uranium as an energy source, but it is plentiful and cheap to produce on the scale of the world demand to the end of the century. The cheap oil supplies will be exploited rather than saved, and oil will continue to be consumed voraciously for transport uses--mainly by the private automobile powered by the internal combustion engine. The present price of oil is artificially high ($10 per barrel) because of the cartel practices of the organization of petroleum exporting countries, OPEC. We expect the price to seek its level with competitive energy supplies almost on a joule for joule level (about $6 per barrel), but, since the resource is scarce, the price

will not go down to the cost of production (which in the rich Arabian fields is only a few cents per barrel). Finally, beyond 1985, the price of oil in units of U.S. man hours will be essentially the same as in pre-OPEC manipulation years. Therefore, cartel operations will result only in a temporary shift in energy related economic activity.

Increased industrial use of energy can be mainly supplied by expansion of our nuclear reactor capacity, as converters at present, and as breeders toward the end of the century. Beyond the year 2000, advanced technology should open up unlimited energy supplies. Candidate sources are coal, fission converters and breeders, hot rock geothermal energy, solar energy, and thermonuclear energy via magnetically confined plasmas or laser implosion fusion.

3.2 An Energy Supply Cycle?

In principle, there is a bountiful energy supply in the future for the entire world and more particularly for the U.S. However, there is a mild shortage in energy availability at present, which is likely to worsen. Energy demands are widely distributed by types of user, while energy supplies are in quite concentrated hands. Expansion of supply has a time delay of from 3-10 years with current oil, coal, or nuclear sources. Really new technology takes from 10-30 years to make itself felt. The time delay can lead to a cyclic instability of energy supply vs demand. At present, users are economizing somewhat on energy consumption, while suppliers are expanding production. But it will be about five years before increases in capacity make extra energy available. Because of repressed demand in the interval, an oversupply will then be available temporarily. Since energy supply is a capital intensive business, once capacity is installed there is high incentive to force use of it. Hence, demand may expand and indeed overshoot in taking up the surplus. We do not have any relevant experience in handling this possible energy supply cycle, but we anticipate considerable difficulty and dislocation of economic effort.

3.3 Effects of Energy Supply on Space Programs

Space programs use little energy for the capital expended, in contrast to most consumer goods industries. Many of the space program economic payoffs,

however, are in more efficient management and use of resources which can save large amounts of energy. On a rationale basis, therefore, times of energy undersupply should be times for expansion of the space program, other things being equal. (A similar comment could be made for the industries in which information is the main product, such as the computer industry.)

3.4 Materials

There are two different types of materials whose short supply might limit industrial growth in the U.S. -- one the relatively rare materials but critically needed in small amounts, such as alloying elements for ferrous alloys; the second, relatively common materials needed in huge amounts, such as aluminum or iron itself.

For the relatively rare materials, we believe that materials science will develop to the point where a large number of substitutes will be found. The total amount of such materials is small, so that even a significant increase in price will not cause any large economic dislocation.

The shortage in common materials is due to the fact that we are using up high grade ores, not due to any lack of the basic materials. Technology is or will be readily developed to extract materials from low grade ores, but at a cost in energy which will be proportional to the mass of material that must be handled. Material shortages then will be one aspect of energy shortages.

Two circumstances will ameliorate the materials shortages in the 1980-2000 period. Although the U.S. will deplete some of the high grade ores, other deposits probably will be found, if indeed they are not already known, in the less well explored areas of the world. Satellite surveillance may be a great aid in their location. While raw materials cartels like OPEC are possible, they are not really likely, and the U.S. should be able to assure supplies from foreign sources on a reasonable cooperative basis. Here again, space programs, including the discovery of the resources through space surveillance, can be an important ingredient of this international cooperation.

Secondly, we may start to "mine" our waste products which are in fact high grade ores for most common materials. The main trouble with waste products as ores is that we are unfamiliar with their exploitation. The wastes are found in far different locations than the natural ores, and we do not have refineries at these locations. (However, the wastes are near the markets of the finished

products.) Furthermore since the wastes contain many unusual substances not found in natural ores, new refining techniques must be developed to separate the desired materials. The by-products in this separation will also be valuable, however, and their recovery may actually pay for the increased costs of refining.

4. INDUSTRY

4.1 Replacement of Capacity

The technological life of an industrial process before it becomes outmoded will significantly decrease, as the rate of technological improvement increases. The valid economic life of industrial capacity will decrease to match. Replacement times of as little as ten years will be common, 30 years will be towards the upper limit even for very large capital-intensive plants. The nation will then essentially renew its entire industrial capacity in less than a human generation.

4.2 Expansion of Capacity

Although population growth will slow down, so that the demand for additional capacity will be only about 25 percent due to increased population by the year 2000, the demand per capita will increase much more than this. By U.S. standards, today one third of our population is considered poor. Satisfying the wants of this one-third fraction in the future will exert a large expansion pressure on our industrial capacity.

The combination of replacement and expansion of industrial capacity will be a stabilizing stimulant to the economic life of the country during the remainder of the 20th century.

4.3 New Industry

In the last 30 years, more than half by value of the products used were unknown previously. Notable examples are TV, computers, jet aircraft, special plastics. The time scale for newness will speed up in the future, and the last 20 years of the 20th century should see capacity in new industry in the U.S. equal to the entire present industial base. The growth in entirely new industry will provide a new type of frontier for the U.S. But as a consequence, some old industries will be pushed out by the new. America has had unusual ability in the past to adapt to change, but this ability will be strained in the

future, as the change cycle becomes more rapid than the human generation cycle. We shall have to face the human readjustment problem as workers will be required to have on the average two very different types of jobs in their careers.

In the future new industry will provide a new base for the space program, much more than the space program will provide new technology for future industry. As a single example, computer hardware for ground use will be developed in small low-powered units to obtain high speed operation and to save on cooling requirements. These characteristics will be desirable and adapted for space application, but the space application will not motivate the development.

In contrast to the replacement and expansion of old industry discussed previously, the development of new industry will be exceedingly unsettling in economic life. New economic methods and new institutions no doubt will be developed to restore a reasonable degree of stability. As one concrete example, the U.S. already has developed a unique government private industry relation in the exploitation of nuclear energy. Vaguely analogous partnerships are predicted for other high capital investment, long term payoff, advanced technology enterprises. We see the federal government providing the risk seed capital now in thermo-nuclear power. We predict this trend will be enlarged in the energy field, and will be established in the field of transportation. As a result, government support of a space program will no longer be regarded as an unusual arrangement.

4.4 A Services Industrial Economy

The complexion of U.S. industry will gradually change during the 1980-2000 period. Foreign countries will develop heavy industry capacity, particularly Western Europe, Japan, and the Soviet Union, with the intent of developing foreign markets. These countries will compete, to a considerable extent successfully, with the United States in supplying the remainder of the world, and even in supplying the domestic U.S. market. While the U.S. will remain a great heavy industry nation, it will not be preeminent. More and more of U.S. industry will be devoted to providing services for people, and servicing capital and consumer goods already in hand. At present, costs of service and repairs on the American automobile during its life about equals the initial purchase price, or stated in another way, the yearly service cost

averaged over the 10-year life, is about 10 percent of the purchase price. Yearly costs of 10 percent for service of purchased goods and capital equipment for other articles may not be unusual in the future.

Personal services also will increase, as affluence increases our demands for personal comforts. As a result, a large share of U.S. industry will be "internalized" -- and serve just to keep the industrial activity in motion. A system with high internalization of this sort becomes both sensitive to disturbances and unstable.

4.5 Persistance of Unprofitable Enterprise

Already we have seen that enterprises like the post office, and the eastern railroads are kept in business despite their failure to generate profits. The U.S. is developing a set of values which go beyond the narrow economic ones in judging the desirability of enterprises. This tendency we expect to expand. Unprofitable industries which provide a desirable public service will be supported in many different forms by the general public. It is predicted that this support will be invoked for the people transportation industry, and probably for freight transport as well. For industries of this type, space programs may very well be acceptable in supporting roles even though they will not be justifiable on strict economic grounds -- after all non-economic value judgments will have been used in evaluating the entire industry.

5. AGRICULTURE

U.S. agriculture, because of the combination of rich soil, favorable climate, advanced technology, and supportive government institutions will be outstandingly productive in the 1980-2000 period and provide large surpluses over domestic needs.

The farms will more and more become vertically integrated in fact as well as in economic form -- they will be food factories with a systems approach towards their product. As this happens, the food factory will be able to program its output to even out seasonal and year to year fluctuations in the basic farm products themselves. This will give stability in both supply and price structure. Appropriate federal legislation will be needed to permit such economic practice, however, since integration might violate anti-trust laws.

The level of technology actually put in use in farming will be considerably greater than that of the best farming practice today, but more important, high

technology farming will become much more widely spread. The farms will be receptive to government supplied technological information for improved production, and will come to rely upon short range and long range weather prediction. On its part, the federal government will continue to regard farming as an essential industry and will give farming extensive support, in the form of technology aids at the least, in outright dollar subsidies if necessary. This precedent for government involvement with the farm will make it easy to justify expensive space programs in support of agriculture, even when, at least in the short run, the programs are not economically justified.

U.S. farm exports will become an important element in international policies in an overall food-tight world. Productivity of the Yellow River Basin in China, and rainfall in the Rift Valley in Africa will be intimately related to what the U.S. will do with its food exports. So global agricultural information, including most particularly that obtained by satellites, will be very much wanted. The worldwide distribution of excess U.S. food above what is required for domestic consumption will become a worldwide issue, which will involve much more than pure economic values. Something beyond the play of the international market place will therefore be invoked to assist in a distribution with elements of justice as well as profit. A cooperative international space program which gives agricultural information may provide the initial base for an amicable cooperative organization to recommend international food distribution patterns.

TECHNOLOGICAL

1. TECHNOLOGICAL MANPOWER

The numbers of scientists and engineers trained in the 1980-2000 period will be far below the optimum number needed for full exploitation of the economic potential of technology -- by about a factor of 3. Nevertheless, the U.S. economy will develop so that it will depend upon large numbers of scientists and engineers with a certain mid-level technical training. The supply of technical manpower will not fulfill this demand, and, as a result, persons from pure science will be recruited into applied science, fron applied science into technology, to partially fill demand.

As shortages of highly trained personnel develop, lower training will be accepted for technology jobs. Jobs will be less well done. Society will see frequent breakdowns in technological equipment, partly resulting from increased utilization, partly from increased complexity, partly from inexpert design, maintenance or operation. Moreover, technologist will become highly specialized so that no person by himself will be able to make things work, and instead teams of technologists will be required.

2. REACTION OF PUBLIC TO TECHNOLOGY AND TECHNOLOGISTS

A high technology culture will be automatically assumed by citizens in the U.S. Despite the high accomplishments of technology, continual nagging failures will dominate the public's perception of technology, and technology and technological personnel will not be held in particularly high regard. General cultural flaws will be blamed on technology, deservedly or not.

Some serious technological calamity is highly probable. In what form it will occur is uncertain. Some possibilities are:

a. Severe accident in a nuclear power plant spreading low level contamination, and causing prolonged plant shutdown. The public will over-react to this.

b. Faulty electric power distribution management, leading to regional power cutoffs.

c. Chemical accident, possibly an explosion, such as in the Texas city disaster.

d. Widespread deleterious side effect of some chemical or biological agent in common use, as a medicine or in agriculture, or in food processing.

e. Computer software failure in some big public service programs -- possibly in banking or government record keeping.

f. Many airliner crashes due to faulty ground systems or an inherent feature of a new class of planes.

g. Killer-smog disasters.

The public and government will tend to over-react to attempt to prevent reoccurrence of such calamities, and both condemn and to some extent stifle technological initiative.

3. TECHNOLOGY PER SE

3.1 General

Technological development is proceeding at a very rapid pace and should continue in an exponential growth. The multiplication time is difficult to know even at present, and hard to predict. As a guess we take the e-folding time as 10 years during the 1980-2000 period.

Some consequences of this rapid growth are very disturbing as regards the stability of our economy and even of our culture. Scientists and technologists will become ignorant in their own field, unless they keep up with progress. An advanced technology education now takes several years. Each 10 years a somewhat similar investment of time is required to maintain a current position in the field. This requirement will strain the capability and the emotional stability of even the very good men in technology -- it probably is beyond the average man in the profession. Beyond a certain age, perhaps 50, only very exceptional individuals will be able to update their education. Even more serious, older men in their 40's and 50's, but in positions of authority because of seniority, will make wrong decisions based upon outdated knowledge, and will in fact oppose new technology applications because of their lack of understanding.

Moreover, whole industries could become obsolescent in the technology multiplication time. An example from the recent past is the fate of the tube type electronic high fidelity equipment industry. Industry will have to reinvest just to renew itself, not to expand its production, and our system will feel the continued stress of this necessity.

We shall make some general prediction of the type of technological development probable during the next 25 years in a very few selected areas. These will serve as examples for similar progress in the many other areas which make up our modern technology.

3.2 Electronics and Computers

Electronics technology will continue its current rapid advance. New types of solid state semi-conductor devices will be developed, and new integrated circuit techniques to match them. Elements will have internally controlled circuit parameters such as variable resistance, including negative resistance, capacitance, inductance, and amplification. Digital methods will be introduced in what are now typically analog type functions for higher quality, and analog devices will replace digital for super compactness.

Computer capability, the combination of speed and complexity of operation, will increase by a factor $10^4 - 10^8$. Cost per unit computation ability in the machines will decrease by almost a corresponding factor. Small computers will cost less than \$10 and will be used as components in many different devices ranging from toys and home appliances to communications and navigation equipment. Truly giant computers, costing $\$10^8$, will be built for industrial and government computer centers.

Computer software will be developed in a hierarchical form and human beings will interact with machines only at the top or next to the top ranks. All lower levels, perhaps 3 or 4, will be done by computers themselves. Of course, while human errors will be eliminated, the machine programs will have unrealized idiosyncrasies, and on rare occasions these will cause catastrophic failures in software systems.

The preceding are only a small selection from the wide range of advances in electronics that is bound to come.

3.3 Materials Sciences

Materials science will pass adolescence and develop into maturity. By this we mean that the science of materials will be understood on a pretty fundamental basis, and therefore materials can be designed to a large extent theoretically for their application. This understanding will probably require enormous computer codes, and the old chemist or metallurgist "feel" for materials will become obsolete.

Big advances will be made in materials for bulk common use, with inexpensive basic matter as the raw material. New forms of plasters, cements, ceramics and glasses will be used in home and factory construction. Also heterogenous materials, and particularly combined natural and synthetic materials, the distant analogs of fiberglass or of plastic laminated wood will be developed.

For advanced technology applications, in small sizes where costs per gram can be high, materials will be available to fit almost any reasonable design specification. Some materials will have extremely anisotropic properties -- for example good thermal conductivity along one axis, poor along another; others will have an unusual combination of properties such as moderate electric conductivity with low heat conductivity. We will have materials of programable and controllable properties, such as rigidity determined by magnetic fields, or electrical properties controlled by pressure, or materials which change their size or shape accurately and predictably as a function of time.

3.4 Laser Technology

Lasers in all forms will be ubiquitous. Lasers will be used in precision measurements, in information processing, in manufacturing processes, in specialized forms of energy transformation, and in specialized energy transport. Low power lasers will be small and inexpensive, adaptable for example to toys, or as a readout system for home music sources such as phonographs. High power pulsed lasers of 10^{12} watts will be developed, and giant lasers with steady power of the order 10^{8} watts are a distinct possibility. Lasers of virtually any frequency from 1000A in the U. V. through the visible, IR and into the microwave will become available, with controllable frequency variation, as well as high precision very narrow band lasers.

Lasers will be employed as interactive components in electronic and in mechanical systems. Also they will find a use in analog data processing.

3.5 Technology Areas for the Space Program

In addition to technology in general, there are specific areas which may have unusually high leverage in affecting the space program. Most, but not all of these areas, were exploited in the conception

of the space initiatives in the body of this report. The following is barely more than a list of some of these areas, which are probably ripe for development in the 1980-2000 period.

(1) Very large objects or arrays in space

These objects may be thin film structures such as balloons, or shades, or they may be made up of disconnected parts, actively maneuvered in place by an information web. Two examples of the latter are a telescope of great focal length in which the focal plane detectors are not physically attached to the objective, and an array of physically separate mirrors acting as a very long base interferometer.

(2) Lasers

Lasers of all types in many different applications.

(3) High peak power, but moderate average power

Used in a variety of specific devices including lasers and masers. Strangely enough no application has been suggested for high intensity pulsed magnetic fields.

(4) Micro-micro electronics

In this category we include the extension of large scale integrated circuit technology, and possible new three dimensional continuum electronics.

(5) Extremely high computer capability

(6) Analog parallel processors and digital parallel processors for information streams, both optical and electronic.

(7) Radiation engineering in the 50-500 μm region.

Here a blending of optical and microwave techniques is possible.

The following additional technology areas were not exploited in formulating space program initiatives in this report, but may well have such applications.

(8) Extremely low temperature - milli-kelvin range

(9) Plasma phenomena

(10) Controlled nuclear explosions

(11) Collective mode accelerators

CULTURAL

1. GENERAL

The cultural changes may be the most important of all the forces that will determine the nature of the space program of the future, for the space objectives must be acceptable, or better, desirable, for the future culture. We have not considered the potential cultural changes in anything like the depth required. The following outline gives an example of the types of thought that we have used, however. The example explores the basis of some attitudes of the future population of the U.S. towards the U.S. Government.

2. SOME LIMITED CULTURAL PREDICTIONS FOR THE YEAR 2000

2.1 Essentially complete disappearance of extended family and the personal and financial security it afforded.

2.2 Consequences of continued high divorce rate become very important in culture.

a. About 80 percent of marriages end in divorce.

b. Mean life of marriage reduced to five years. Average number of partners taken in one lifetime - 40 years ÷ 5 years = 8 partners.

c. Children will be brought up in constantly changing family environment. In 15 years of youth, each child will see an average of three parent pairs.

d. Children will not be able to depend on a stable family for support, primarily of emotional, but importantly of financial nature. They will depend upon government institutions--schools, and later, various agencies of health, education, and welfare.

2.3 Almost complete cultural emancipation of women.

a. 90 percent of women in working force (c.f. 60 percent today).

b. Women competing for "man's" jobs, although employment ratio will still favor men.

c. Complete change in male attitude towards working women. Women regarded as job competitions.

As competition they are not to be regarded as entitled to current male "protectionist" attitude. In perception as well as in fact they are to be exploited to the limit of male capability (which will not be high).

Many "easy" liasons between working men and women further diluting home and family ties.

d. Women take large share in government --
50 percent of government workers will be women
30 percent of middle management in government will be women
20 percent of high executives
20 percent of legislatures (local, state, federal)

e. Consequences of women in government.
Emphasis on immediate practicalness of programs.
De-emphasis on long term ideals, goals, and on principles.
More personal involvement in government with people.
Government actions less circumscribed by logical consistency, and also less predictable.

2.4 Increased turning to and dependence on government for services, security, support -- in effect a substitution of government institutions for the extented family.

U.S. GOALS IN SPACE EXPLOITATION 1980-2000: CIVIL AREA

The set of trends, events, possible developments, that may characterize the last part of this century that has just been discussed in this appendix form an amorphous background of material on which to develop rational goals for a space program of the 1980-2000 period. Actually in this work no rigorous pattern of deductive reasoning was used to go from this background to a set of goals. Instead a set of goals was suggested by the potential capabilities of space systems, and then ordered under logical categories significant for human welfare under almost any projection of historical circumstances. The list of goals was then tested and found to be consistent with the amorphous background just described. More or less emphasis can then be placed on specific goals as they seem more or less important in the future historical context. The following table lists the goals, and some specific space activities or systems which aid in their attainment.

U.S. GOALS IN SPACE EXPLOITATION 1980-2000: CIVIL AREA

A. MATERIALISTIC

1. Promotion of international peace

   U.N. satellite peacekeeping system

   Heads of state "hot line" communication

2. Aid in U.S. position of world leadership

3. Aid in optimum industrial activity.

   Exploration for land resources

   Monitoring of industrial activity and wastes

   Management of ocean resources

   Weather prediction and warning

   Overseeing transportation

   Provision of universal communications

4. Aid in agricultural and forest management

   Weather prediction, warning and control

   Worldwide crop prediction and management

   Forest surveying and management

5. Provision of new resources from space

   Solar energy (if economical)

6. Acquisition of new technological capabilities from space environment

   Extremely high vacuum conditions

   High purity surfaces

   Zero gravity processes

7. Use of space to remove hazards from earth

   Dangerous industrial processes

   Disposal of waste products, including radioactive material

8. Preparation for space habitation

B. HUMANISTIC AND PUBLIC SERVICE

1. International cooperation - brotherhood of man

    Manned research laboratory in space

    Multinational communication system

2. Aid to general safety

    Hurricane warning

    Flood warning - long term, months; short term, hours

    Earthquake prediction

    Tsunami location and warning

    Drought diagnosis

    Transportation safety

3. Protection of the general environment

    Pollution monitoring

    Preservation of the ozone layer

    Prediction of ionospheric disturbances

4. Individual aid and protection

    Worldwide search and direction of personal rescue

5. Crime Control

    Personal emergency communications

    Anti-personal crime measures

6. Internal security

    Boundary surveillance

    Control of radioactive materials to prevent diversion and blackmail

7. Improved relations of citizens to government

8. Enhancement of individual satisfaction

   Planetary exploration

C. INTELLECTUAL

1. Aid in determination of origin and early history of the solar system

   Planetary exploration and geology

   Nature of asteroids

   Cometary research

2. Aid in understanding of galactic structure and dynamics

   Infrared astronomy using wavelengths from 5-500 μm

   UV astronomy

3. Aid in understanding cosmology

   X-ray astronomy

   Observations of distant objects - all electromagnetic frequencies

   Intergalactic material - particles, atoms and ions, molecules

   Low noise measurement of 3K universal background black body radiation

4. Verification of physical laws in the large

   General relativity experiments

   Invariance, spatial and temporal of velocity of light

   Homogeneity of "empty" space

   Isotropy of "empty" space in the large

5. Precision measurements to verify physical laws in the small

   Precise value of gravitational constant

   Equivalence of inertial and gravitational mass

Pages A-34 through A-84 discuss future environments, goals, and space functional requirements in the military sector. They are deleted for security classification reasons.

APPENDIX B

WEIGHT ESTIMATION

APPENDIX B

WEIGHT ESTIMATION

I. INTRODUCTION

The purpose of this appendix is to present, in an abbreviated form, the results of the Study 2.5 activity so far and the groundrules and methodology used to generate those results.

II. LAUNCH VEHICLE ELEMENTS

Launch vehicle design and rocket performance computations are outside the scope of this effort. Nevertheless, it is necessary to define a set of candidate launch vehicle elements in gross terms in order to conduct the study. The selected launch vehicle combinations are listed in Table I, together with their estimated gross payload capabilities. The payload weights represent deployment only; the costs represent launch costs only.

The candidate launch vehicle element set is by no means exhaustive, but is considered to be sufficiently comprehensive to serve the objectives of the Study 2.5 activity.

All launch vehicle elements are considered to be reusable and are identified as follows:

Element A

A standard shuttle with characteristics approximating to the NASA April 1974 shuttle configuration.

Element B

A Large Launch Vehicle (LLV), not defined in detail, but providing approximately 20 times the payload capability of Element A to low earth orbit.

Element C

A standard tug upper stage having performance capability approximately equivalent to the Interim Cryogenic Space Tug described in NASA Baseline Space Tug Document (see Reference 1).

Item	Launch Vehicle Combination	Code	Low Altitude		High Altitude			Launch Veh. Cost/Flight $\$ \times 10^{-6}$*
			Low Inclination	High Inclination	Elliptical	Geosynch.	Translunar	
1	Shuttle	A	60,000	30,000	-	-	-	12.0
2	Shuttle + Tug	A + C	-	-	15,000	7,000	6,000	13.0
3	Shuttle + Tandem Tug	2A + 2C	-	-	37,000	18,000	15,000	26.0
4	Shuttle + Large Tug	A + D	-	-	24,000	11,000	10,000	14.0
5	Shuttle + Large Tandem Tug	2A + 2D	-	-	60,000	29,000	24,000	28.0
6	Shuttle + SEPS	A + E	-	-	21,000	10,000	8.500	12.5
7	Shuttle + Nuclear	A + G	-	-	42,000	20,000	17,000	15.0
8	Shuttle + Tug + SEPS	A + C + E	-	-	30,000	14,000	12,000	13.5
9	Shuttle + Large Tug + Large SEPS	A + D + F	-	-	48,000	22,000	19,000	14.5
10	LLV	B	1,200,000	600,000	-	-	-	15.0
11	LLV + Large Tug	B + D	-	-	300,000	140,000	120,000	17.0
12	LLV + Large SEPS	B + F	-	-	420,000	200,000	170,000	16.0
13	LLV + Nuclear	B + G	-	-	840,000	400,000	340,000	18.0
14	LLV + Large Tug + Large SEPS	B + D + F	-	-	600,000	280,000	240,000	18.0

Table I. Candidate Launch System Payload Capabilities (lb)

CODE: A = Shuttle
B = LLV (Large Launch Vehicle)
C = Tug
D = Large Tug
E = SEPS (Solar Electric Propulsion Stage)
F = Large SEPS
G = Nuclear Stage

*Does not include amortization of RDT&E costs

Element D

A large tug, not defined in detail, but providing approximately a 60% increase in payload capability to geosynchronous orbit over the A + C combination, when combined with the standard shuttle.

Element E

A Solar Electric Propulsion Stage (SEPS) similar to the configuration described by Rockwell International (RI) and used by RI in their SEPS applications studies (See Reference 2).

Element F

A large SEPS, not defined in detail, but when combined with the LLV, providing 20 times the payload capability to geosynchronous orbit as the A + E combination.

Element G

A nuclear upper stage which utilizes an advanced nuclear orbital propulsion system having an I_{sp} comparable to the solar electric propulsio stage, but a thrust level comparable to present-day chemical rockets.

In order to permit investigation of the potential utility of SEPS from low earth orbit, it is assumed:

(a) By the time period of interest, solar cells will be developed which are highly resistant to radiation degradation .

(b) Long transfer times (280-350 days) to final orbit are acceptable for most of the initiatives.

(c) The nuclear stage is considered for initiatives where on-orbit maneuvering is an essential characteristic of the mission (for instance, for survivability) and the satellite orbital configuration is large.

(d) The SEPS and the nuclear stage are available on-orbit for extended periods of time and do not require refurbishment after every use. The costs listed in Table I reflect this assumption.

III. MISSION EQUIPMENT ADVANCED TECHNOLOGY

During the course of the study, a number of new mission equipment concepts were identified which would require technological advances to develop and deploy. In addition to large, lightweight solar arrays, nine generic types were identified and these can be divided into two specific categories. In addition, all the nine generic types appear to have the common characteristic of needing large structural assemblies in space. These

structural assemblies may or may not need to be rigid structures.

The hierarchical structure is illustrated in Figure 1, together with the code numbers of the initiatives which appear to be candidates for utilizing the nine generic concepts. Briefly, the nine generic types can be described as follows:

Type 1

Type 1 is a plane optical reflector subject to relatively low flux densities. It provides a large aperture rather than a small spot size and therefore a surface quality considerably below the diffraction limit is adequate. It is constructed of a thin mylar or kapton film rigidized by a graphite composite deployable structure. The rigid structure supports the necessary housekeeping subsystems.

Type 2

Type 2 is a spherical optical reflector subject to relatively low flux densities and requiring the same surface tolerance as Type 1. It is constructed of a double layer of thin mylar or kapton film, sealed at the edges, one layer being silvered and one layer being clear. By pressurizing the space between the layers, an approximately parabolic surface is realized. Structural rigidity is maintained by a pressure stabilized toroidal edge structure constructed by utilizing the Goodyear "Airmat" concept. The necessary housekeeping subsystems, including the attitude control thrusters, are located on this outer ring structure.

Type 3

Type 3 is an optical reflector which is subject to relatively low flux densities, but requires close surface tolerance control and, therefore, cannot be made of thin mylar or kapton film. Instead, it is a rigid structure of graphite composite with the front face silvered and the back face used to radiate surplus heat. The necessary housekeeping subsystems are attached to the mirror. The mirror may or may not be gimballed.

Type 4

Type 4 is an optical reflector which is subject to high flux densities and also requires close surface tolerance. It is therefore constructed of a rigid graphite epoxy structure, heavier than Type 3 because of a heavier and more complex thermal control system. The necessary housekeeping subsystems are attached to the mirror and the mirror may or may not be gimballed.

- Large, Lightweight Space Structures
  - Solar Cell Array
  - Optical
    - Low quality, low temperature, plane, optical reflector (Type 1)
      - MS-8, CS-6
    - Low quality, low temperature, parabolic, optical reflector (Type 2)
      - MO-21, MO-22
    - High quality, low temperature, plane, optical reflector (Type 3)
      - MO-3, MO-7, MO-15, MO-23, MO-24, MS-2, CO-2, CO-10
    - High quality, high temperature, optical reflector (Type 4)
      - MC 15, MW-8, M S-3, MS- 9, MS-12, CS-5, CS-8
  - Microwave
    - Passive microwave reflector (Type 5)
      - MO-6, MO-11
    - Passive microwave antenna (Type 6)
      - CO-8, CO-9
    - Active microwave antenna (Type 7)
      - MW-7, CS-1, CS-3
    - Bootlace lens multibeam antenna (Type 8)
      - MC-1, MS-1, CC-1, CC-10
    - Dielectric lens multibeam antenna (Type 9)
      - MO-4, MC-13, MW-4, CC-2, CC-3, CC-4, CC-7, CC-8, CC-9, CS-10

Figure 1. Large, Lightweight Space Structure Applications

Type 5

Type 5 is a simple microwave reflector constructed of a very lightweight open metalized graphite epoxy cobweb structure or a thin mylar or kapton film with printed circuit type dipoles. The structure may be deployed, assembled on-orbit or possibly even fabricated on-orbit. A housekeeping subsystem package is required.

Type 6

Type 6 is a microwave antenna, constructed in a similar way to Type 5, but is electronically more complex to allow beam formation and is, therefore, heavier and more costly.

Type 7

Type 7 is an active microwave antenna which radiates microwave energy generated in orbit, normally to the ground. Conceptually, it is similar to a configuration described by Arthur D. Little, Inc. (See Reference 3).

Type 8

Type 8 is a near-term technology medium-sized multibeam antenna which utilizes the bootlace lens concept. Conceptually, it is similar to a configuration studied by the Hughes Aircraft Company (See Reference 4).

Type 9

Type 9 is a far-term technology large-sized multibeam antenna using very lightweight structures and incorporating a dielectric lens.

IV. TYPE 1 CONCEPTUAL DESIGN

1. Design

Detailed design is outside the scope of the Study 2.5 effort. However, a conceptual design was developed for the Type 1 optical reflector and is illustrated in Figure 2.

Figure 2 illustrates a triangular planform shape of reflector which is based on previous study activities described in Reference 5. The method used for supporting the three sides of the reflector in tension uses a catenary support concept. Support is provided at each of the three corners of the reflector

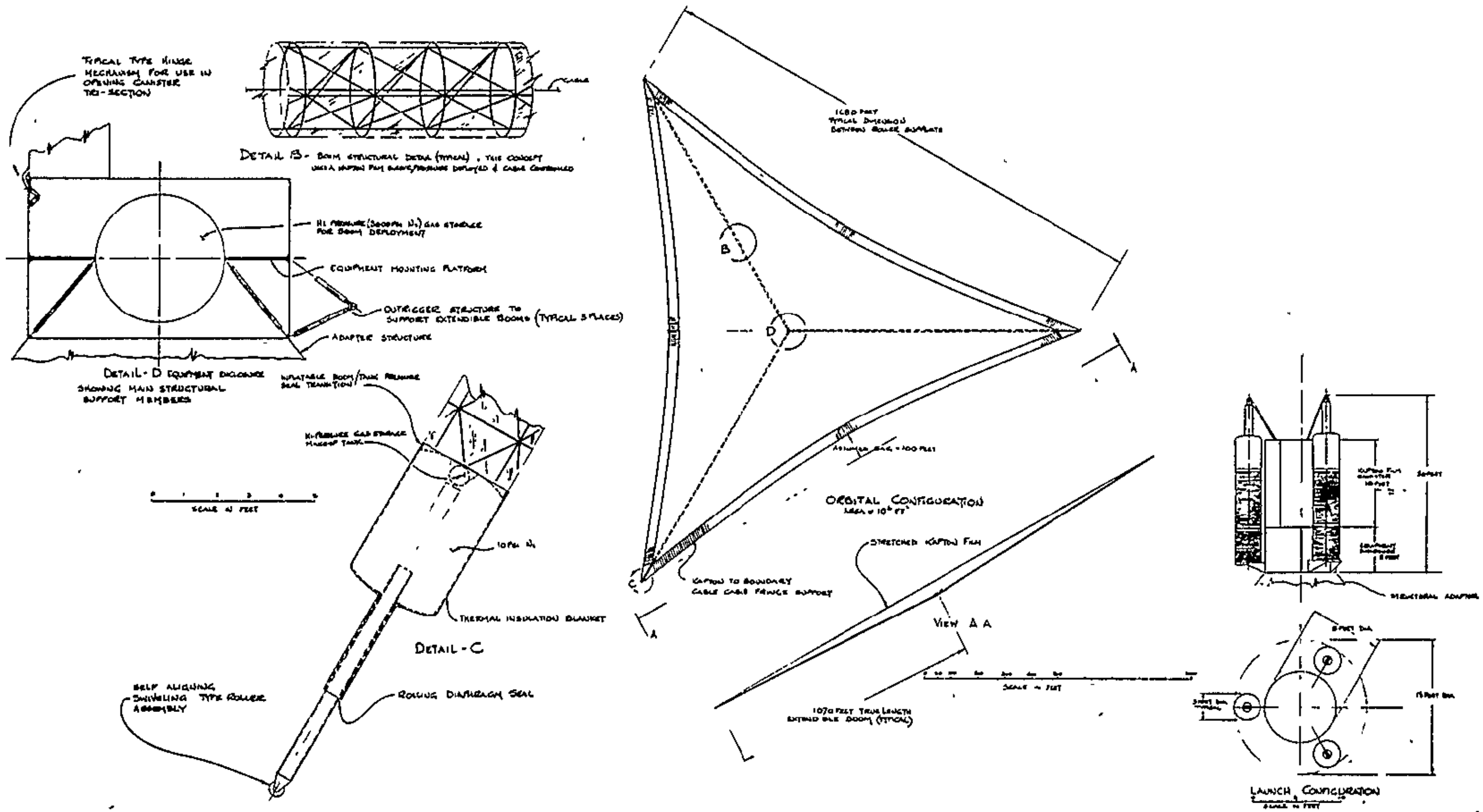


Figure 2. Type 1 Optical Reflector

by booms that deploy from the central spacecraft structure. The primary difference between Figure 2 and the configuration shown in Reference 5 is that the concept presented makes use of a complete triangular film reflector in contrast to a three segment reflector. The single reflector eliminates the necessity for supporting the radial edge members of the respective segments.

The reflector is assumed to be fabricated from .00025 in. kapton polyimide film in contrast to the present state of the art polyimide film thickness of .0005 in. The edges of the triangular shaped film are connected to the edge cable (catenary support) by means of a myriad of separate cables which forms essentially a continuous attachment that eliminates undesirable side forces which would tend to wrinkle the film. Based on information contained in Reference 5, the kapton is assumed to be stressed at 10 psi. This film stress was used to determine the loads required at the corners of the reflector, (and, hence, the ends of the booms), to stretch the reflector to obtain a taut surface. The 10 psi stress level is defined as the minimum stress (Reference 5) required to remove wrinkles in the material. The corner loads that were derived, using the 10 psi stress level and assuming the catenary to have a 100 ft sag, were computed to be 260 lb at each corner.

A thermal excursion of $\pm 425^{\circ}F$ was assumed to derive the expansion/contraction dimensional changes in the kapton film. Based on a thermal expansion of 2.0×10^{-5} in/in/$^{\circ}C$, the length of each corner of the reflector was estimated to vary $\pm$ 3 ft. Detail C, shown in Figure 2, shows a pressure cylinder and sliding member for adjusting the boom length to accommodate the $\pm$3 ft deflection associated with maintaining a taut reflector surface. The cylinder dimensions, (diameter = 3 ft, length = 4 ft), and internal pressure, (10 psi), were selected to minimize the force variation that would occur at the end of the sliding member due to the expansion/contraction of the kapton. The maximum and minimum end loads computed for the fully extended and retracted positions were 234 and 286 lb respectively, based on the assumption that the temperature of the pressurant would remain constant. It was further assumed

that the pressurant can be maintained at a constant temperature by insulating the external surfaces. Discussions held with thermal control specialists indicated that, in all probability, low power consumption heaters would be required to maintain the gas at constant temperature. A high pressure gas tank (12.0 in. dia; 3000 psi) is incorporated inside the main tank to provide the necessary makeup gas that may be required due to possible leakages occurring in the seal of the sliding member.

A concept depicting a typical structural arrangement utilizing three booms is shown in Detail B. The section properties of each boom were computed, using an equation in Reference 6, assuming an end load of 280 lb and a boom length of approximately 1100 ft. Each of the three boom longerons shown in Detail B are 0.3 in. in diameter. The boom assembly is inscribed in a circle 36 in. in diameter. The frame spacing is 36 in. The boom concept depicted in Detail B does not define in detail the specific folding technique that is necessary to collapse the structure for the launch phase. Further study effort would be required to determine methods for folding and deploying the structure as well as maintaining the deployed alignment accuracy.

The launch configuration is also shown in Figure 2. A canister used to house the kapton reflector is provided and is supported from the equipment enclosure. The canister consists of three sections that may be rotated away from the enclosure during deployment. The three booms, equally spaced about the canister, are hinge-supported from the equipment enclosure. An adapter structure attached to the equipment enclosure is also defined to indicate typical interface characteristics and identifies a method that may be used to react loads introduced due to the launch environment.

2. Weights

Two weight statements for the concept described above are given in Tables II and III. Table I assumes conventional attitude control thruster clusters located at the apexes of the triangular structure. However, although insufficient resources were available to

SIZE: 1680 ft side

SHAPE: Triangle

AREA: 1,000,000 ft^2

REFERENCE: Thin kapton film; chemical thrusters at triangle apexes

	Weight (lb)	Cost* Weight (lb)	Ratio
STRUCTURE	7602	8742	0.604
ELECT. POWER	242	278	0.019
TT&C	150	173	0.012
GUID. & NAV.	1222		
		1455	0.101
ACS INERTS	44		
ACS PROPELL.	445	512	0.035
MISSION EQUIP.	2888	3320	0.229
LIFE SUPPORT	-	-	-
CONTINGENCY	1888	-	-
TOTAL WT.	14,481	14,481	1.000
UNIT WT. = 0.01185 lb/ft^2			

*Distributed contingency

Table II. Type 1 Conceptual Design Weight Statement - Chemical Thrusters

SIZE: 1680 ft side
SHAPE: Triangle
AREA: 1,000,000 ft^2
REFERENCE: Thin kapton film; distributed ion thrusters

	Weight (lb)	Cost* Weight (lb)	Ratio
STRUCTURE	6371	7327	0.136
ELECT. POWER	33,086	38,048	0.709
TT&C	150	173	0.003
GUID. & NAV.	310		
		1277	0.024
ACS INERTS	800		
ACS PROPELL.	3084	3546	0.066
MISSION EQUIP.	2888	3321	0.062
LIFE SUPPORT	-	-	-
CONTINGENCY	7003	-	-
TOTAL WT.	53,692	53,692	1.000
UNIT WT. = 0.04393 lb/ft^2			

*Distributed contingency

Table III. Type 1 Conceptual Design
Weight Statement - Distributed Ion Thrusters

conduct a dynamic analysis, it is suspected that a distributed attitude control system (e. g., an ion thruster system) would be required for such a large structure. If this were the case, the weight would be increased and this increase is reflected in Table III.

V. SATELLITE LIFETIME

Satellite lifetime parameters that are of interest are as follows:

(a) System useful life

(b) Satellite design life

(c) Satellite MTBF

(d) Satellite MMD

(e) Satellite resupply or service period (for satellites which are resupplied on orbit).

(f) Satellite module lifetime parameters (for satellites which are modularized for replacement of failed subsystem components on orbit).

Associated with each of the above characteristics is a probability that it will be achieved. Of secondary importance are the probabilities associated with assembling, on orbit, a satellite which is composed of separately launched subassemblies and with achieving an operational state.

Lifetime parameters for future systems are notoriously difficult to estimate and, in any case, a detailed reliability investigation is inappropriate for the Study 2. 5 effort. For this reason, the following judgmental factors were used to assign lifetime characteristics to the initiatives of interest.

Discussions with LMSC and TRW personnel have established that a 10 year design life for communication satellites is possible in the near-time. For DOD satellites, 10 years is very close to the system useful life. Certain components on near-term observation satellites tend to limit their design lifetime to about 5 years and to consider deploying a 10 year observation satellite would involve provisions having to be made for cleaning lenses, replacing critical components and so on.

Space servicing studies have indicated that 3 year servicing intervals are a reasonable compromise, considering launch costs, increased costs required to make a satellite space serviceable, and the uncertainties associated with the general space servicing concept.

For the purposes of the Study 2.5 effort, therefore, it was assumed that, in general, all satellites would be designed for space servicing and that they would have a 10 year design life (assumed coincident with useful life) and a 3 year service period.

Exceptions to the above rule are as follows:

(a) Certain low altitude observation satellites utilizing large telescopes which need adjustment by man. These are serviced at 1 year intervals.

(b) Manned systems which are serviced at 1 year intervals.

(c) Highly survivable systems which are not serviced.

(d) Very large, high cost space assembled satellites which are considered to be capable of being updated by on-orbit block changes and have virtually unlimited life.

VI. WEIGHT ESTIMATION

In order to estimate the weights of the approximately 80 initiatives of interest with the limited resources and time available, the initiatives were first divided into three groups:

(a) Satellites which can be approximated to near-term design communication satellites.

(b) Satellites which can be approximated to near-term design observation satellites.

(c) Far-term satellites which incorporate advanced technology and utilize non-traditional mission equipment advanced design concepts.

Category (c) was further divided into the nine generic types described briefly in Section III. A specific example for each of these generic types was selected and the weights estimated. These weights were then extrapolated to determine the weights of other satellites which utilized mission equipment of the same generic types, but having different performance characteristics (such as size and power).

Because of the limited resources available, considerable dependence was placed on existing study results. This is summarized in Table IV which identifies the contractor references used to construct typical weight statements for the nine generic types. These weight statements are given in Tables V throuth XIII.

Type Number	Description	Contractor Reference
1	Optical Reflector - Thin Film Mirror	Reference 5
2	Optical Reflector - Double Thin Film Mirror	Reference 5
3	Optical Reflector - Cool Graphite Epoxy Mirror	Reference 7
4	Optical Reflector - Hot Graphite Epoxy Mirror	Reference 7
5	Passive Microwave Reflector	Reference 5
6	Passive Microwave Antenna	Reference 8
7	Active Microwave Antenna	Reference 9
8	Bootlace Lens Multibeam Antenna	Reference 4
9	Dielectric Lens Multibeam Antenna	Reference 4

Table IV. Large Space Structure Types

SIZE: 400 ft side
SHAPE: Triangle
AREA: 69,200 ft^2
REFERENCE: Thin Kapton Film

	Weight (lb)	Cost* Weight (lb)	Ratio
STRUCTURE	693	796	0.680
ELECT. POWER	20	23	0.020
TT&C	10	12	0.010
GUID. & NAV.	90	115	0.098
ACS INERTS	10		
ACS PROPELL.	40	46	0.039
MISSION EQUIP. (FILM)	156	179	0.153
LIFE SUPPORT	---	---	-----
CONTINGENCY	152	---	-----
TOTAL WT.	1171	1171	1.000
UNIT WT. = 0.016922 lb/ft^2			

*Distributed contingency

Table V. Type 1 (Optical Reflector - Thin Film Mirror) Typical Weight Statement

SIZE: 400 ft side
SHAPE: Triangle
AREA: 69,200 ft^2
REFERENCE: Thin Kapton Film

	Weight (lb)	Cost* Weight (lb)	Ratio
STRUCTURE	667	767	0.564
ELECT. POWER	33	38	0.028
TT&C	10	12	0.008
GUID. & NAV.	104	133	0.098
ACS INERTS	12		
ACS PROPELL.	46	53	0.039
MISSION EQUIP. (FILM)	311	358	0.263
LIFE SUPPORT	---	---	-----
CONTINGENCY	177	---	-----
TOTAL WT.	1360	1360	1.000
UNIT WT. = 0.01965 lb/ft^2			

*Distributed contingency

Table VI. Type 2 (Optical Reflector - Double Thin Film Mirror) Typical Weight Statement

SIZE: 16.4 ft dia
SHAPE: Circular
AREA: 211.2 ft^2
REFERENCE: Cool Mirrors = 10 lb/ft^2

	Weight (lb)	Cost* Weight (lb)	Ratio
STRUCTURE	558	642	0.115
ELECT. POWER	60	69	0.012
TT&C	50	57	0.009
GUID. & NAV.	300	1665	0.297
ACS INERTS	1148		
ACS PROPELL.	650	747	0.133
MISSION EQUIP. (MIRROR)	2112	2429	0.434
LIFE SUPPORT	----	----	-----
CONTINGENCY	731	----	-----
TOTAL WT.	5609	5609	1.000
UNIT WT. = 26.54 lb/ft^2			

*Distributed contingency

Table VII. Type 3 (Optical Reflector - Cool Graphite Epoxy Mirror) Typical Weight Statement

SIZE: 16.4 ft dia

SHAPE: Circular

AREA: 211.2 ft^2

REFERENCE: Hot Mirrors = 30 lb/ft^2

	Weight (lb)	Cost* Weight (lb)	Ratio
STRUCTURE	1836	2111	0.177
ELECT. POWER	60	69	0.006
TT&C	50	58	0.005
GUID. & NAV.	300	1665	0.139
ACS INERTS	1148		
ACS PROPELL. (2 YRS)	650	748	0.063
MISSION EQUIP. (MIRROR)	6336	7286	0.610
LIFE SUPPORT	----	----	-----
CONTINGENCY	1557	----	-----
TOTAL WT.	11,937	11,937	1.000
UNIT WT. = 56.573 lb/ft^2			

*Distributed contingency

Table VIII. Type 4 (Optical Reflector - Hot Graphite Epoxy Mirror) Typical Weight Statement

SIZE: 4500 x 4500 ft (64 modules)
SHAPE: Square
AREA: 20,250,000 ft^2
REFERENCE:

	Weight (lb)	Cost* Weight (lb)	Ratio
STRUCTURE	128,827	148,151	0.703
ELECT. POWER	1180	1357	0.006
TT&C	6400	7360	0.035
GUID. & NAV.	1200	2624	0.012
ACS INERTS	1082		
ACS PROPELL.	5131	5900	0.028
MISSION EQUIP. (REFLECTOR)	39,488	45,412	0.216
LIFE SUPPORT	-------	-------	-----
CONTINGENCY	27,496	-------	-----
TOTAL WT.	210,804	210,804	1.000
UNIT WT. = 0.01041 lb/ft^2			

*Distributed contingency

Table IX. Type 5 (Passive Microwave Reflector) Typical Weight Statement

SIZE: 88.6 x 16,405 ft
SHAPE: Rectangle
AREA: 1,453,500 ft^2
REFERENCE: Ion Propulsion

	Weight (lb)	Cost* Weight (lb)	Ratio
STRUCTURE	9907	11,393	0.427
ELECT. POWER	700	805	0.030
TT&C	100	115	-----
GUID. & NAV.	400	1840	0.069
ACS INERTS	1200		
ACS PROPELL.	3668	4218	0.158
MISSION EQUIP. (ANTENNA)	7329	8428	0.316
LIFE SUPPORT	----	------	-----
CONTINGENCY	3495	------	-----
TOTAL WT.	26,799	26,799	1.000
UNIT WT. = 0.018437 lb/ft^2			

*Distributed contingency

Table X. Type 6 (Passive Microwave Antenna) Typical Weight Statement

SIZE: 3,281 ft dia
SHAPE: Circular
AREA: 8,450,500 ft^2
REFERENCE: Ion Propulsion

	Weight (lb)	Cost* Weight (lb)	Ratio
STRUCTURE	593,477	682,499	0.116
ELECT. POWER	574,069	660,179	0.112
TT&C	100	115	-----
GUID. & NAV.	6,500	352,475	0.060
ACS INERTS	300,000		
ACS PROPELL.	21,320	24,518	0.004
MISSION EQUIP. (ANTENNA)	3,630,000	4,174,500	0.708
LIFE SUPPORT	-------	-------	-----
CONTINGENCY	768,820	-------	-----
TOTAL WT.	5,894,286	5,894,286	1.000
UNIT WT. = 0.697508 lb /ft^2			

*Distributed contingency

Table XI. Type 7 (Active Microwave Antenna) Typical Weight Statement

SIZE: 131.23 ft dia
SHAPE: Circular
AREA: 13,537 ft^2
REFERENCE: Boòtlace Lens

	Weight (lb)	Cost* Weight (lb)	Ratio
STRUCTURE	623	717	0.018
ELECT. POWER	150	173	0.004
TT&C	220	253	0.006
GUID. & NAV.	525	932	0.023
ACS INERTS	285		
ACS PROPELL.	1245	1432	0.036
MISSION EQUIP. (LENS)	31,947	36,737	0.913
LIFE SUPPORT	------	------	-----
CONTINGENCY	5249	------	-----
TOTAL WT.	40,244	40,244	1.000
UNIT WT. = 2.9729 lb/ft^2			

*Distributed contingency

Table XII. Type 8 (Bootlace Lens Multibeam Antenna) Typical Weight Statement

SIZE: 131.23 ft dia
SHAPE: Circular
AREA: 13,537 ft^2
REFERENCE: Dielectric Lens

	Weight (lb)	Cost* Weight (lb)	Ratio
STRUCTURE	1041	1197	0.200
ELECT. POWER	150	173	0.029
TT&C	220	253	0.042
GUID. & NAV.	175	385	0.064
ACS INERTS	160		
ACS PROPELL.	260	299	0.050
MISSION EQUIP. (LENS)	3195	3674	0.615
LIFE SUPPORT	----	----	-----
CONTINGENCY	780	----	----
TOTAL WT.	5981	5981	1.000
UNIT WT. = 0.441826 lb/ft^2			

*Distributed contingency

Table XIII. Type 9. (Dielectric Lens Multibeam Antenna) Typical Weight Statement

A certain amount of interpolation between present-day technology and year 2000 technology was necessary. The way in which this was accomplished to aid in deriving power system weights is illustrated in Figure 3. Figures 4 through 9 illustrate the relationship between size and weight for the different types of mission equipment.

VII. INITIATIVE MISSION EQUIPMENT

An examination of each initiative was made to determine what kind of mission equipment would satisfy its primary mission requirements. Basic descriptions for each satellite were determined and are listed in Tables XIV through XX.

VIII. INITIATIVE DATA SHEETS

Using the weight models described in Section VI, weights for the whole spectrum of initiatives were developed. These are listed in Tables XXI through XXVII. Also listed in Tables XXI through XXVII are other design parameters which are required as input to the cost estimating computer program, such as a launch vehicle combination for each initiative.

In accordance with the scope and depth appropriate to this part of the design activity, performance analyses were not used to select launch vehicle combinations. Instead, Table I was utilized to come to a judgmental decision for each specific case. In most cases a modularized version of each large satellite could be conceived and therefore the shuttle vehicle, combined with an appropriate upper stage could handle the mission in an acceptable number of flights. The maximum number of shuttle flights identified for a single initiative is 120 (for MW-7). The initiative spectrum includes a number of extremely large satellites and, for these, the LLV was selected. The maximum number of LLV flights identified for a single initiative is 500 (for MW-8).

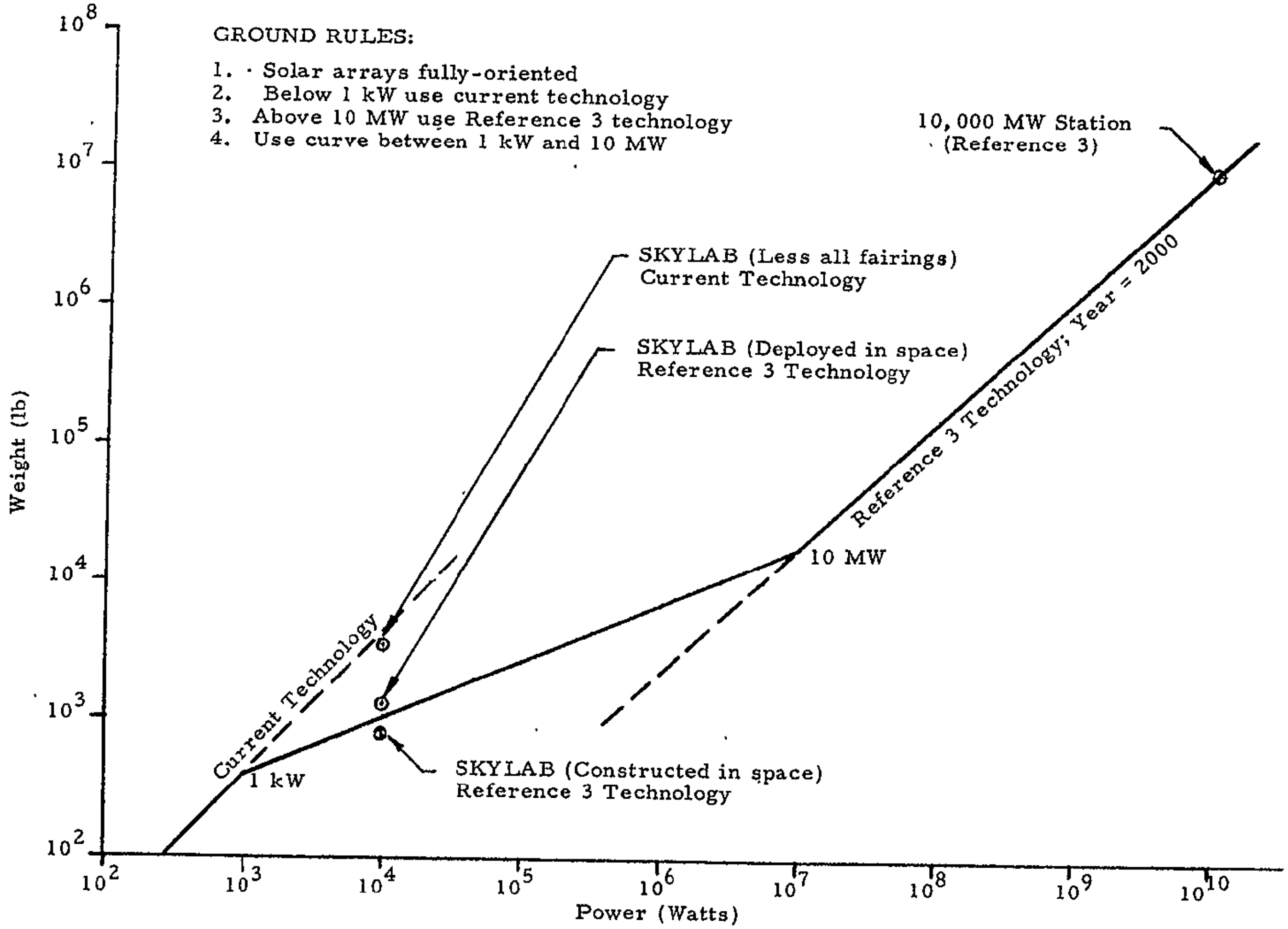


Figure 3 - Electrical Power System Weight vs. Power Level

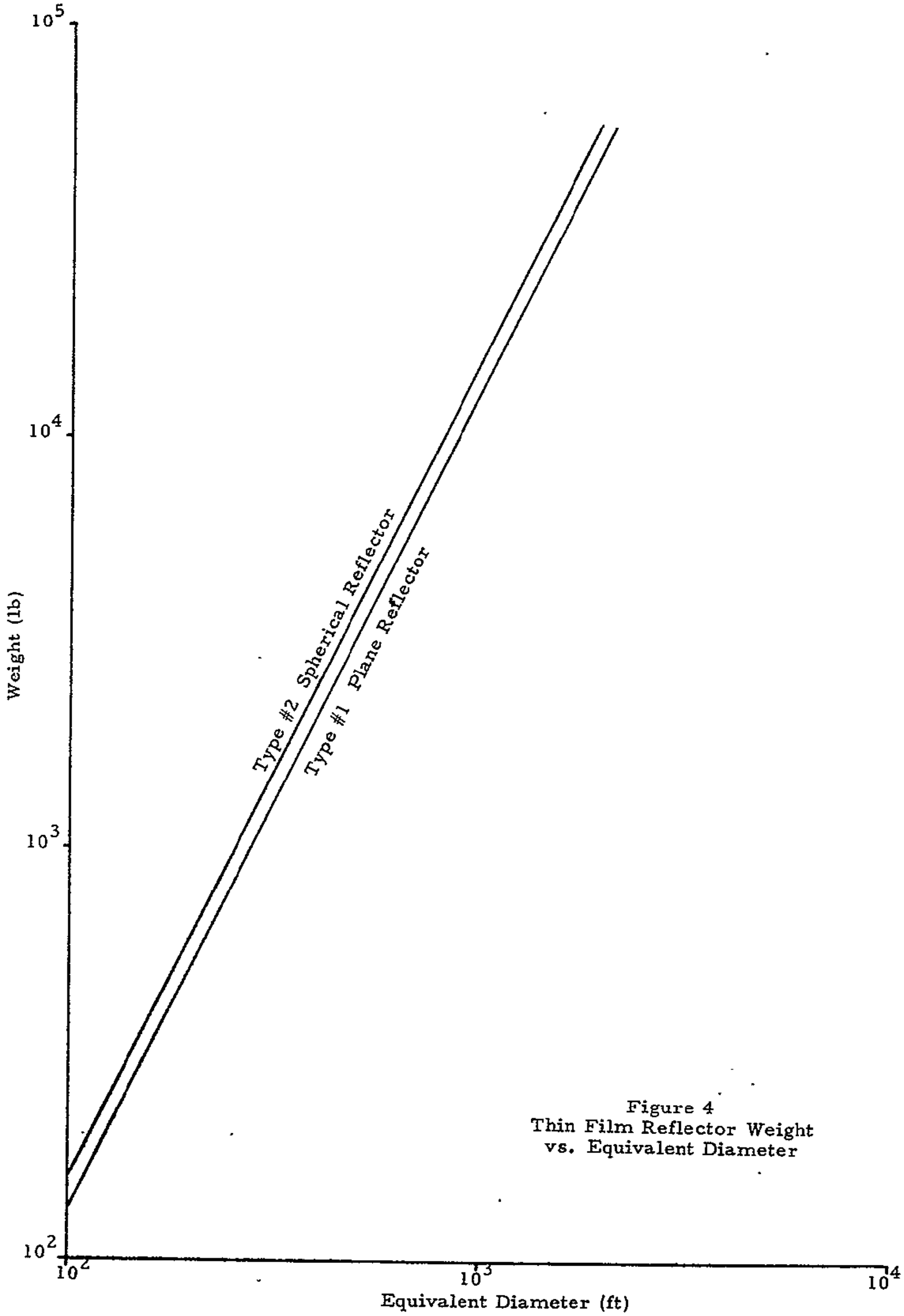


Figure 4
Thin Film Reflector Weight
vs. Equivalent Diameter

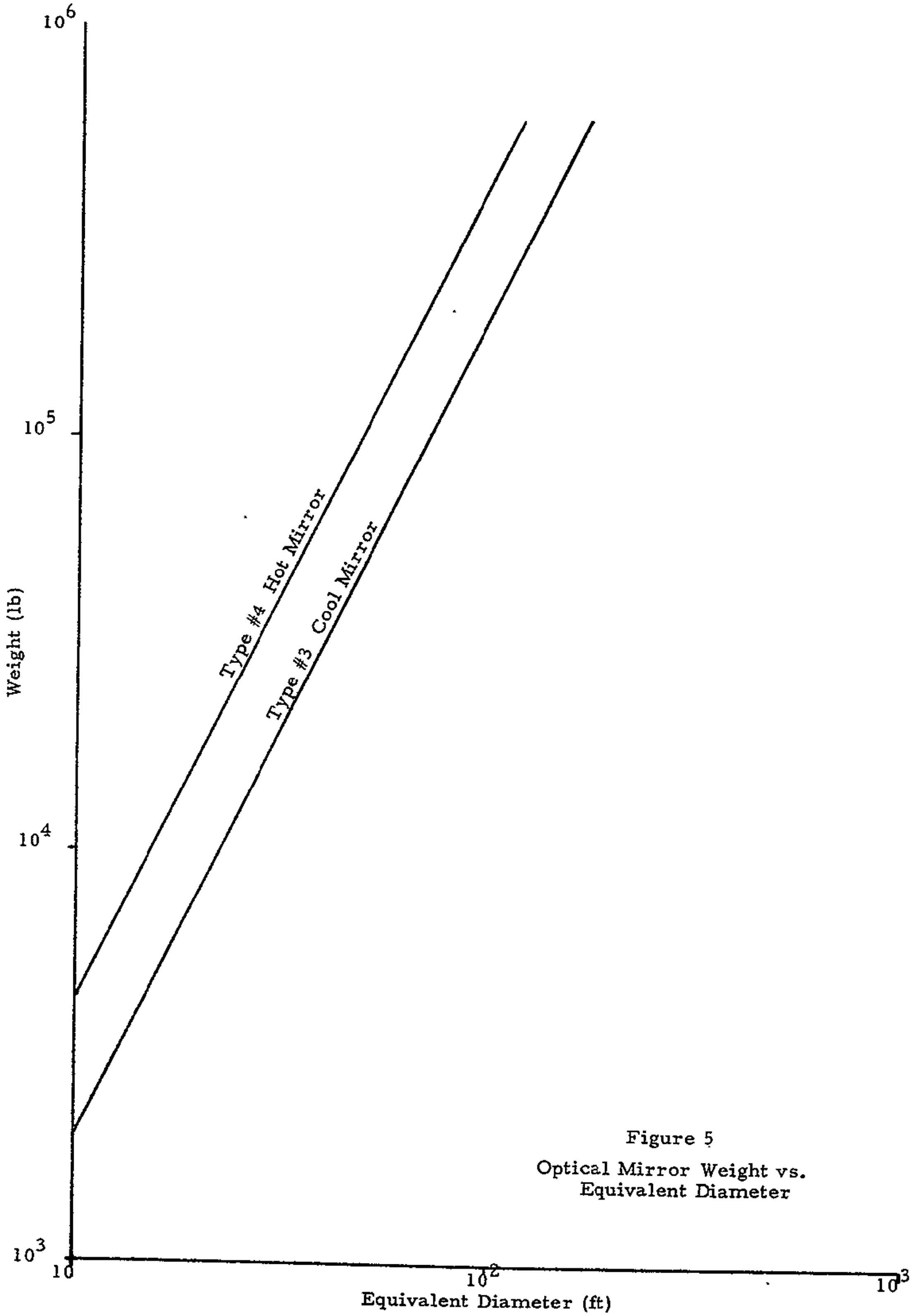


Figure 5
Optical Mirror Weight vs.
Equivalent Diameter

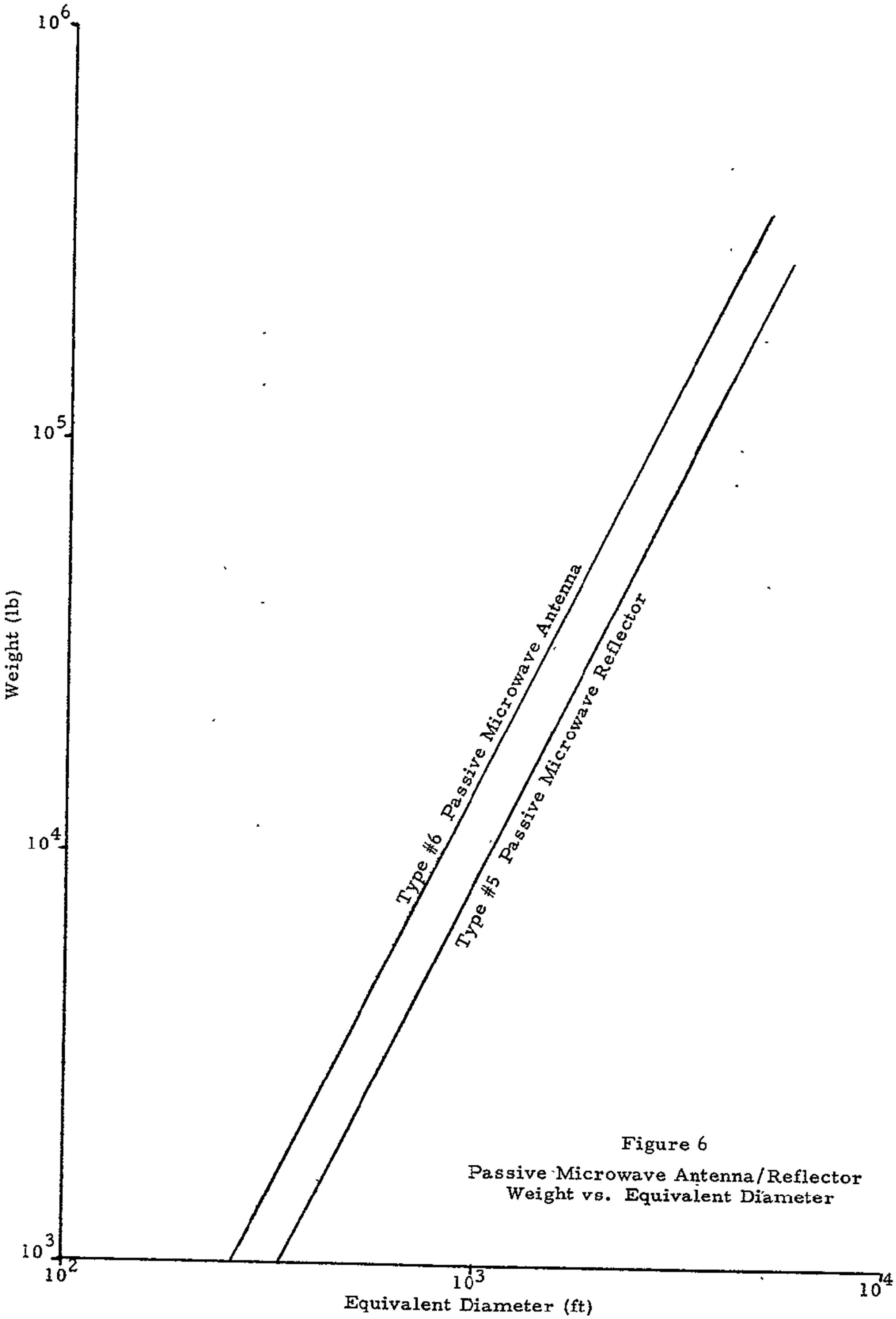


Figure 6

Passive Microwave Antenna/Reflector
Weight vs. Equivalent Diameter

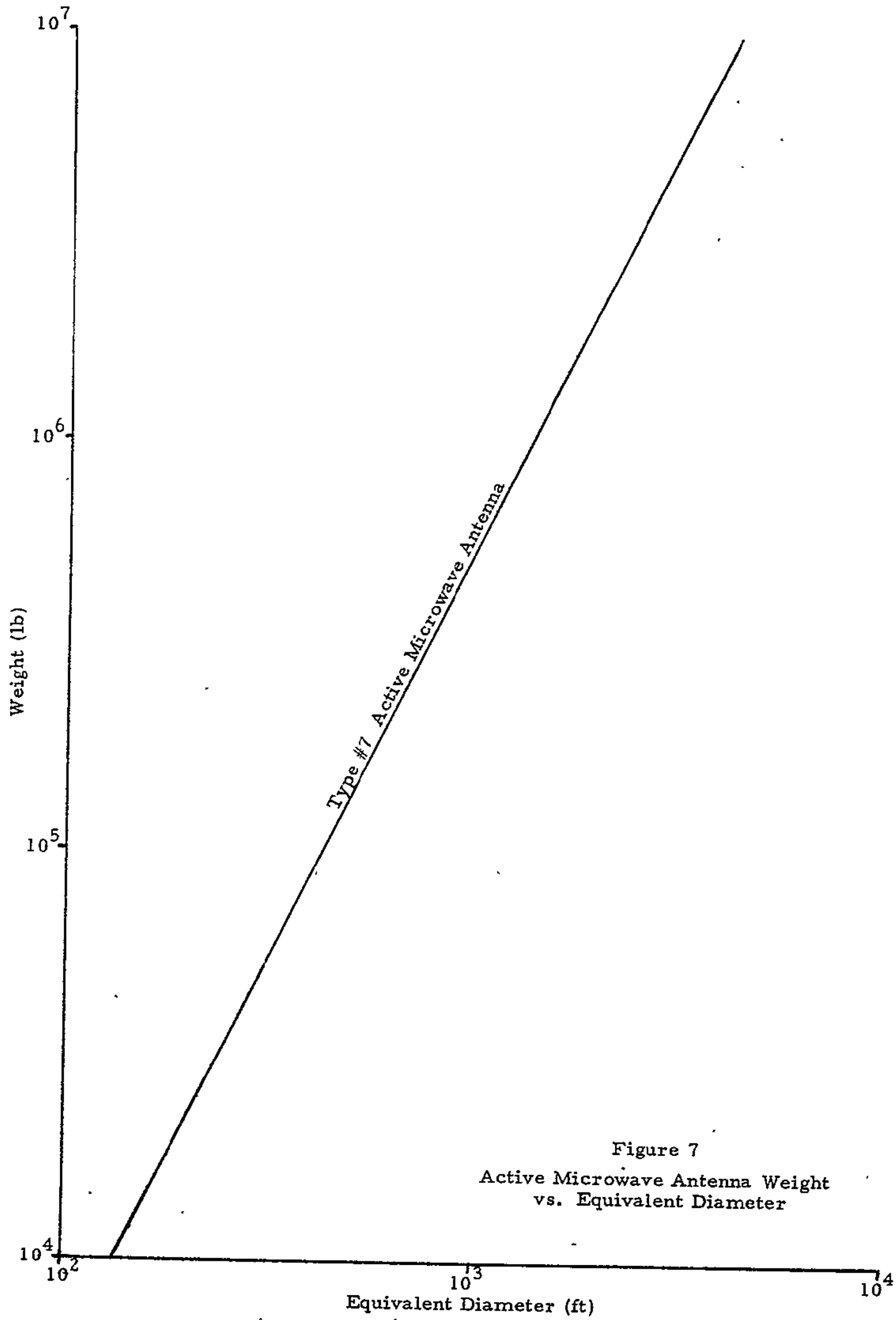


Figure 7
Active Microwave Antenna Weight
vs. Equivalent Diameter

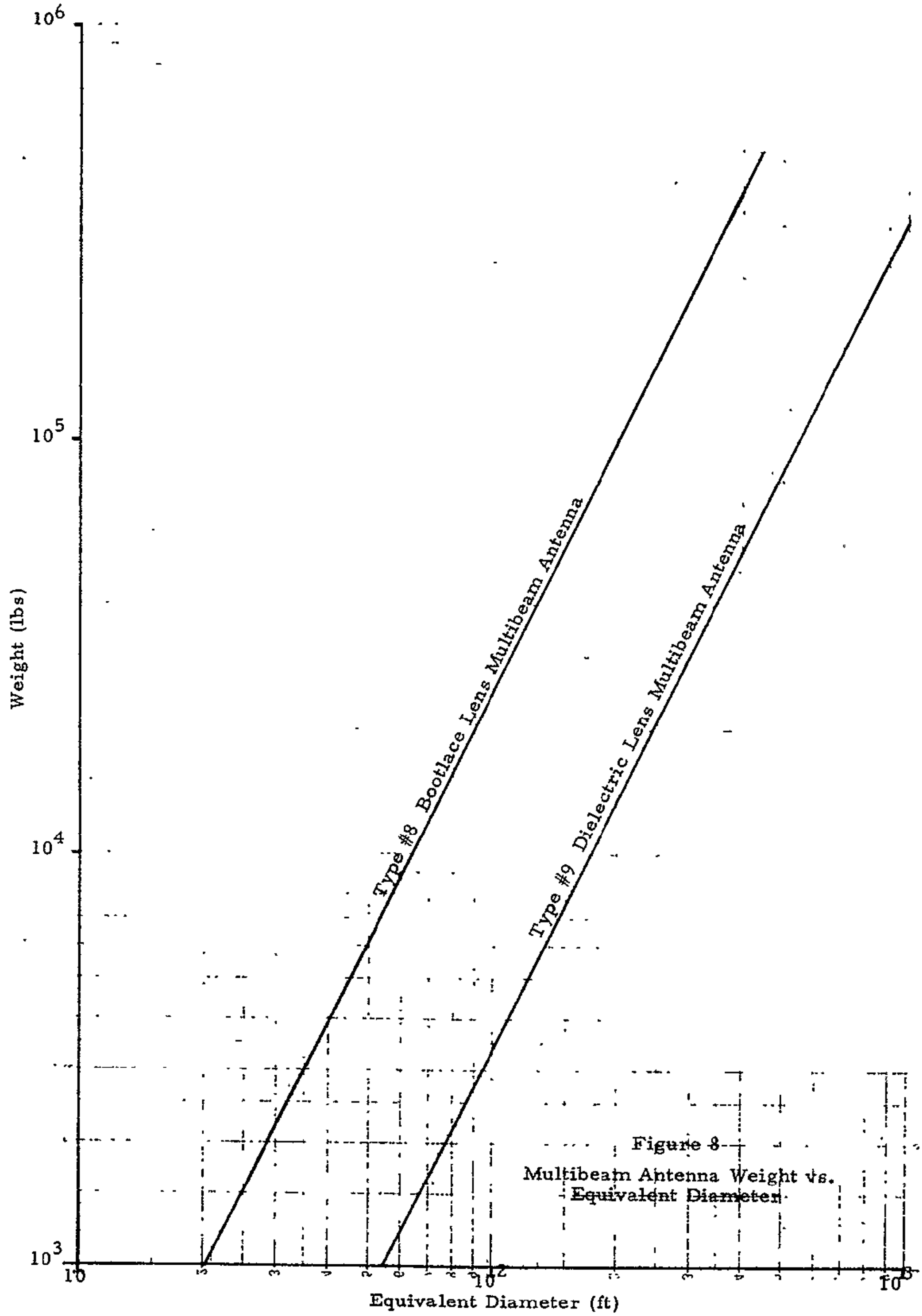


Figure 8

Multibeam Antenna Weight vs. Equivalent Diameter

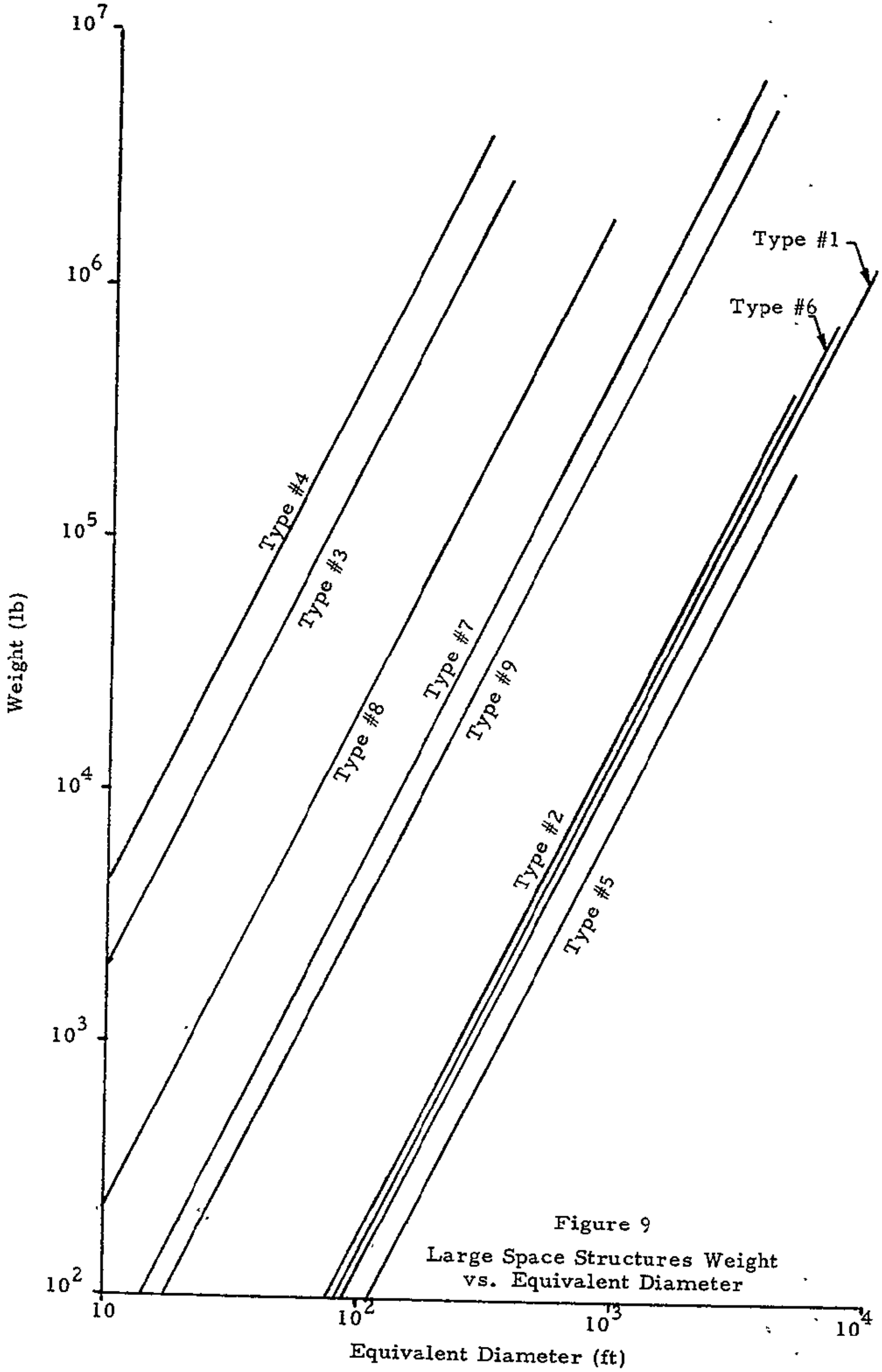


Figure 9

Large Space Structures Weight vs. Equivalent Diameter

Pages B-33 through B-36 describe the basic characteristics of the major sensors used on each of the military satellites catalogued in this report. They are omitted for security classification reasons.

CODE	PRIMARY MISSION EQUIPMENT
CO-1	6 ft dia optics multi-spectral telescope; side-looking radar
CO-2	10 ft dia optics IR sensor
CO-6	10 ft dia optics, 10 degree FOV telescope
CO-7	4 ATS-type antennas, 18 ft dia ea
CO-8	10 x 5,000 ft Type 6 antenna
CO-9	2 crossed Type 6 antennas, 10 n mi long; #1 = 9 ft wide, #2 = 90 ft wide
CO-10	2 crossed arrays of Type 3 mirrors, 770 ft long, 44 mirrors 6.6 ft dia ea; stationkept focal plane satellite
CO-11	10 ft dia mm wave antenna; pulsed CO_2 laser

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Table XVIII. Primary Mission Equipment - Civilian Observation

CODE	PRIMARY MISSION EQUIPMENT
CC-1	13 ft dia, 10 beam Type 8 antenna
CC-2	150 ft dia, 260 beam (250 fixed, 10 scanning) Type 9 antenna
CC-3	150 ft dia, 250 fixed beam Type 9 antenna
CC-4	150 ft dia, 100 beam Type 9 antenna
CC-5	COMSATS
CC-7	150 ft dia, 100 beam Type 9 antenna
CC-8	150 ft dia, 100 beam Type 9 antenna
CC-9	150 ft dia, 25 beam Type 9 antenna
CC-10	5 ft dia, 200 beam Type 8 antenna

Table XIX. Primary Mission Equipment - Civilian Communications

CODE	PRIMARY MISSION EQUIPMENT
CS-1	370 ft dia, X-band Type 7 antenna
CS-2	Large thermoelectric plant fueled by nuclear waste. Powers satellites on orbit
CS-3	Large solar energy plant; 2.6 x 7.3 n mi; 3280 dia Type 7 antenna beams power to earth
CS-4	Tug nuclear waste disposal
CS-5	169 Type 4 mirrors, 15 ft dia ea, stationkept
CS-6	100 Type 1 reflectors, 300 ft dia ea, stationkept
CS-10	120 ft dia, 100 beam Type 9 antenna
CS-11	Propulsive stage for deorbiting space debris
CS-12	Chemical spray ozone replenishment
CS-13	2 crossed Type 6 antenna, 1 nm x 1 ft ea

Table XX. Primary Mission Equipment - Civilian Support

Pages B-40 through B-49 present the design data used to estimate the IOC costs for the military initiatives catalogued in this report. They are omitted for security classification reasons.

Table XXV. Initiative Design Data - Civilian Observations

CODE	CO-1	CO-2	CO-6	CO-7	CO-8	CO-9
TITLE	Advanced Resource Polling Observatory	Forest Fire Detection	U.N. Truce Observatory	Nuclear Fuel Location	Border Surveillance	Coastal Passive Radar
Orbit Apogee (n mi)	500	19,300	225	19,300	19,300	19,300
Constellation Size	4	1	1	1	1	3
IOC Date	1985	1990	1990	1995	1990	1995
Launch Vehicles	A	A; D	A	A; C	A; C	A; D; F
Number of Flights	4	A=2, D=2	1	A=2; C=2	A=1; C=1	A=5; D=5; F
Type of Structure	ENDO	ENDO	ENDO	ENDO	EXO	EXO
Type of ACS	3-Axis	3-Axis	3-Axis	3-Axis	3-Axis	3-Axis
Type of EPS	Solar	Solar	Solar	Solar	Solar	Solar
Power-Begin. Life	12 kW	2 kW	3 kW	700 W	12 kW	600 kW
Weight:						
Structure (lb)	7,500	3,800	600	4,000	1,200	45,000
EPDS (lb)	1,300	600	700	300	1,200	6,000
TT&C (lb)	300	150	200	400	50	100
ACS; G&N (lb)	700	350	300	800	200	7,500
Propellant (lb)	200	100	200	1,000	300	17,500
Mission Equipment (lb)	20,000	20,000	2,000	1,500	400	35,000
Life Support (lb)	-	-	-	-	-	-
Total Weight (lb)	30,000	25,000	4,000	8,000	3,350	111,000
Size (ft)	10 x 60	15 x 60	15 x 40	4 @ 18 dia ea	5000 x 10	10 n mi x 9; 10 n mi x 90
Design life/Serv. Period (yrs)	10/3	10/3	10/3	10/3	10/3	10/3
IOC Cost ($)	710M	230M	190M	560M	170M	1.1B

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Table XXV. Initiative Design Data - Civilian Observations (Contd.)

CODE	CO-10	CO-11				
TITLE	Astronomical Telescope	Atmospheric Temperature Profile Sounder				
Orbit Apogee (n mi)	300	600				
Constellation Size	2	4				
IOC Date	2000	1990				
Launch Vehicles	A	A; E				
Number of Flights	A=2	A=1; E				
Type of Structure	ENDO	ENDO				
Type of ACS	3-Axis	3-Axis				
Type of EPS	Solar	Solar				
Power-Begin. Life	10 kW	50 kW				
Weight:						
Structure (lb)	5,000	750				
EPDS (lb)	6,000	2,200				
TT&C (lb)	200	50				
ACS; G&N (lb)	12,000	600				
Propellant (lb)	5,000	250				
Mission Equipment (lb)	15,000	250				
Life Support (lb)	-	-				
Total Weight (lb)	43,200	4,100				
Size (ft)	2 @ 770 x 6.6	10 dia				
Design life/Serv. Period (yrs)	10/1	10/3				
IOC Cost ($)	690M	340M				

Table XXVI. Initiative Design Data - Civilian Communications

CODE	CC-1	CC-2	CC-3	CC-4	CC-5	CC-7
TITLE	Global Search and Rescue	Disaster Control	Urban Police Wrist Radio	Electronic Mail Transmission	Transportation Services Satellite	Polling and Voting System
Orbit Apogee (n mi)	19,300	19,300	19,300	19,300	8,000	19,300
Constellation Size	20	1	1	1	20	1
IOC Date	1980	1990	1990	1990	1985	1990
Launch Vehicles	A; C	A, C; E	A, C, E	A; C; E	A; C	A; C; E
Number of Flights	A=10; C=10	A1, C=1; E	A=1; C=1, E	A=1, C=1; E	A=20; C=20	A=1, C=1; E
Type of Structure	ENDO	ENDO	ENDO	ENDO	ENDO	ENDO
Type of ACS	3-axis	3-axis	3-axis	3-axis	3-axis	3-axis
Type of EPS	Solar	Solar	Solar	Solar	Solar	Solar
Power-Begin. Life	500 W	1.5 kW	1.5 kW	3.0 kW	600 W	1.5 kW
Weight:						
Structure (lb)	1,020	1,600	1,600	1,600	450	1,600
EPDS (lb)	120	500	500	900	250	500
TT&C (lb)	200	300	300	300	50	300
ACS; G&N (lb)	260	500	500	500	150	500
Propellant (lb)	200	400	400	400	200	400
Mission Equipment (lb)	200	4,800	4,800	4,800	300	4,800
Life Support (lb)	-	-	-	-	-	-
Total Weight (lb)	2,000	8,100	8,100	8,500	1,400	8,100
Size (ft)	13 x 7	150 dia	150 dia	150 dia	6 x 8	150 dia
Design life/Serv. Period (yrs)	10/3	10/3	10/3	10/3	10/3	10/3
IOC Cost ($)	700M	270M	270M	280M	620M	270M

Table XXVI. Initiative Design Data - Civilian Communications (Contd.)

CODE	CC-8	CC-9	CC-10			
TITLE	National Information Services	Personal Communication	Diplomatic U/N Hot Line			
Orbit Apogee (n mi)	19,300	19,300	19,300			
Constellation Size	4	1	3			
IOC Date	1990	1990	1980			
Launch Vehicles	A; C; E	A; D	A; C			
Number of Flights	A=4; C=4; E	A=1; D=1	A=3; C=3			
Type of Structure	ENDO	ENDO	ENDO			
Type of ACS	3-axis	3-axis	3-axis			
Type of EPS	Solar	Solar	Solar			
Power-Begin. Life	3 kW	21 kW	1 kW			
Weight:						
Structure (lb)	1,600	1,700	1,600			
EPDS (lb)	900	1,500	400			
TT&C (lb)	300	300	200			
ACS; G&N (lb)	500	500	300			
Propellant (lb)	400	400	400			
Mission Equipment (lb)	4,800	4,800	100			
Life Support (lb)	-	-	-			
Total Weight (lb)	8,500	9,200	3,000			
Size (ft)	150 dia	150 dia	5 x 15			
Design life/Serv. Period (yrs)	10/3	10/3	10/3			
IOC Cost ($)	420M	320M	230M			

Table XXVII. Initiative Design Data - Civilian Support

CODE	CS-1	CS-2	CS-3	CS-4	CS-5	CS-6
TITLE	Energy Generation Plant Nuclear	Energy Generation Plant - RTG	Energy Generation Plant - Solar	Nuclear Waste Disposal	Laser Aircraft Beam Power	City Night Illuminator
Orbit Apogee (n mi)	19,300	1,000	19,300	Escape	300	19,300
Constellation Size	1	1	1	1	100	1
IOC Date	2000	2000	2000	1990	2000	1990
Launch Vehicles	B; D; F	B, D, F	B; D; F	A; D	B; F	A, D
Number of Flights	B=280; D=280; F	B=50; D=50, F	B=90; D=90, F	A=2; D=2	B=300; F	A=14 ; D=14
Type of Structure	EXO	ENDO	EXO	ENDO	ENDO	ENDO
Type of ACS	3-Axis	3-Axis	3-Axis	3-Axis	3-Axis	3-Axis
Type of EPS	Nuclear Reactor	RTG	Solar	Solar	Solar	Solar
Power-Begin. Life	13,000 MW	12 MW	10,000 MW	4 kW	85 kW	250 W
Weight:						
Structure (lb)	11,000,000	3,000,000	7,090,000	27,500	372,000	97,500
EPDS (lb)	65,000,000	12,000,000	14,550,000	750	3,000	10,000
TT&C (lb)	4,000	4,000	4,000	250	9,000	5,000
ACS. G&N (lb)	50,000	10,000	15,000	5,000	285,000	14,000
Propellant (lb)	250,000	160,000	25,000	28,000	130,000	6,000
Mission Equipment (lb)	4,700,000	6,000	3,620,000	2,500	1,240,000	17,500
Life Support (lb)	-	-	-	-	-	-
Total Weight (lb)	81,004,000	15,180,000	25,304,000	64,000	2,039,000	150,000
Size (ft)	3600 dia	114 dia	7.3 x 2.6 n mi	15 x 60	169 @ 15 dia ea	100 @ 300 dia ea
Design life/Serv. Period (yrs)	1000/3	>25/3	>25/3	N/A	10/3	10/3
IOC Cost ($)	15.7B	3.5B	10.9B	430M	67.4B	1.1B

Table XXVII. Initiative Design Data - Civilian Support (Contd.)

CODE	CS-10	CS-11	CS-12	CS-13		
TITLE	Vehicle Speed Control	Space Debris Sweeper	Ozone Layer Replenishment/ Protection	Inexpensive Navigation System		
Orbit Apogee (n mi)	19,300	19,300	80 - 120	19,300		
Constellation Size	3	1	1	1		
IOC Date	1990	1985	1985	1990		
Launch Vehicles	A; D	A; C	A	A, C		
Number of Flights	A=3 ; D=3	A=10; C=1	A=140	A=1, C=1		
Type of Structure	ENDO		N.A.	EXO		
Type of ACS	3-Axis		N.A.	3-Axis		
Type of EPS	Solar		N.A.	Solar		
Power-Begin. Life	200 kW		N.A.	1 kW		
Weight:						
Structure (lb)	2,000		-	450		
EPDS (lb)	4,000		-	400		
TT&C (lb)	200		-	100		
ACS; G&N (lb)	600		-	100		
Propellant (lb)	500	510,000	-	200		
Mission Equipment (lb)	2,500		-	100		
Life Support (lb)	-		-	-		
Total Weight (lb)	9,800		8,000,000	1,350		
Size (ft)	120 dia	N.A.	N.A.	2 @ 1 n mi x 1		
Design life/Serv. Period (yrs)	10/3	N.A.	N.A.	10/3		
IOC Cost ($)	610M	130M	1.7B	130M		

IX. REFERENCES

1. Baseline Tug, MSFC Report, MSFC 68M00039-2, dated July 15, 1974.
2. Extended Definition Feasibility Study for a Solar Electric Propulsion Stage (SEPS) Concept Definition. Rockwell International Space Division Report, SD73-SA-0132-1, Volumes I, II, III, IV, dated Dec. 21, 1973.
3. Glaser, Peter E., et al, Feasibility Study of a Satellite Solar Power Station. Prepared for Lewis Research Center. Arthur D. Little Report No. ADL-C-74830 (NASA Report No. NASA CR-2357), dated February 1974.
4. Kummer, Wolfgang H., Final Report for Advanced General Purpose Forces Satellite Antenna Study. Prepared for Space and Missile Systems Organization. Hughes Report No. 2265.30/215, (SAMSO-TR No. 74-71), dated December 1973.
5. Nash, A. G., Briefing - Aerospace Corporation Analysis and Extension of NASA ABLE Studies. Aerospace TOR-1001(2525-19)-2, dated 1 March 1967, (Confidential)
6. Astromasts for Space Applications. Astro Research Corporation, Santa Barbara.
7. Young, C. H., Briefing - Graphite Composite Applications to High-Energy Laser Systems. General Dynamics Report 20054VCE, undated.
8. Briefing - Spaceborne Radar Study. Grumman Aircraft, undated.
9. Final Briefing - SSPS Structure/Control Interaction. Grumman Aircraft (NASA Contract NAS-3-16804), dated February 1973.

APPENDIX C

COST ESTIMATION

APPENDIX C

COST ESTIMATION

I. INTRODUCTION

A computerized cost model was used to generate Study 2.5 initiative cost estimates. The use of such models allows rapid analysis of a large number of programs in a systematic way. Briefly, the model:

(a) Accepts the physical, performance, and programmatic data listed in Tables XXI through XXVII of Appendix B on each satellite considered.

(b) Applies cost-estimating relationships that reside in the model to the data.

(c) Simultaneously provides consistent program cost estimates for all satellite programs.

The model also accepts adjustment factors to enable special cases to be handled, such as the effect on cost of specific advanced technologies. In the current study, a principal concern is the estimation of costs for extremely large structures for future space applications.

The cost model is described below in terms of the inputs it requires, the output it produces and the special considerations that must be taken into account for this particular study. In addition, a discussion of the assumptions underlying the cost estimates is presented.

II. COST MODEL INPUTS

The model is oriented towards subsystems; hence, it requires as inputs, physical and performance data that relate to the following subsystem categories:

(a) Structures (including environmental control and payload assembly and integration).

(b) Electrical Power

(c) Communications (including telemetry, tracking and command and data processing).

(d) Stability and Control (including guidance, navigation, stabilization, and attitude control).

(e) Mission Equipment

Typical hardware items included in the above subsystem categories are listed in Table I.

The required spacecraft subsystem inputs are:

(a) Structures - weight
- structure type

(b) Electrical Power - weight
- beginning of life wattage

(c) Communications - weight
- orbit apogee
- orbit perigee

(d) Stability and Control - dry weight
- propellant weight
- number of control axes

In addition to subsystem information, certain program data is also required. This includes the number of satellites in the constellation and estimates of AGE and SE & TD costs. If time-phasing of funding requirements is a desired output, cost spreading functions and schedules of flights must be included. Finally, if launch costs are to be considered, launch vehicle type, numbers of each vehicle needed, and schedules of uses must be inputted.

III. COST MODEL OUTPUT

The model produces several types of output, depending on the needs of the user. First, a one-page detail sheet is printed for each satellite program. It contains a summary of the subsystem input information, subsystem and total satellite basic estimates for RDT&E and for unit cost, schedule input data showing numbers of satellites and years flown and time-phased funding for RDT&E, Investment (unit cost times number of satellites) and Operations (launch site support).* The basic cost estimate outputs for all the satellite initiatives considered in this study are shown in the attached computer printout.

*If servicing of satellites is performed, servicing costs are also included in Operations.

Table I. Payload Subsystem Definition

Subsystem Element	Typical Hardware
Structures, Mechanisms (All structural and mechanical elements which are not part of the other functional subsystems. Also includes install. of sub-systems into spacecraft, attachment of experiments and docking system for retrievable satellites.)	• Spacecraft Structure • Equipment Supports • Sun Baffles • Balance Booms and Extns. Mech. • Antenna Deployment Mech. • Solar Array Deployment Mech. • Retrieval Docking Ring
Environmental Control (All elements which alter and/or control the temperature of the payload and components thereof.)	• Thermal Louvers • Insulation • Thermal Paints and Coatings • Thermostats • Heaters • Radiators, Heat Pipes
Guidance, Navigation, and Stabilization (All elements which provide flight control, orbit positioning, and attitude hold, but excluding thruster system.)	• Position Sensors (Solar, Earth, Star) • Momentum Wheels • Flight Control Electronics • Gyros • Inertial Ref. Units
Propulsion (All elements which are provided for major changes in velocity vectors.)	• Solid-Propellant Motors • Monopropellant or Bi-Propellant Thrusters • Tankage for Propellant, Pressurants • Plumbing and Valves • Propellant, Pressurants
Attitude Control (Elements for control and/or maintenance of attitude which involve mass expulsion.)	• Cold Gas, Monopropellant or Bi-Propellant Thrusters • Tankage for Propellant, Cold Gas, Pressurants • Plumbing and Valves • Propellant, Pressurants
Command, Data Processing, Instrumentation (All elements of Data Processing, instrumentation, telemetry communications and command.)	• Data Hdlg., Processing, Storage Equipment • Signal Conditioners • Transducers • Transmitters, Beacons, Transponders • RCVRS/Decoders • Multiplexers/Encoders • Antennas • RF Power Amplifiers • CMD. Data Storage, Timing
Electrical (All elements of electrical power generation, control, distribution. Also includes pyrotechnic hardware.)	• Batteries • Solar Arrays (Incl Structural Panels, Solar Cell Diodes, Interconnects, Orientation Assy) • Voltage Regulators, Inverters • Distrib., Primary and Inst. Cabling • Pyrotechnic Devices (Squibs, etc.)
Mission Equipment (All elements which are mission-peculiar and not part of the supporting spacecraft. Includes any data processing equipment which is integral with experiments.)	• Telescopes • Cameras • TV Cameras • Physics Experiments • Radiometers, Spectrometers, etc.
Payload Assembly, Integration (All elements which are part of the payload system but do not remain with the payload in orbit.)	• Payload Adapters and Interstages • Fairings (not Std. Exit) • Umbilicals • Safety Devices • Separation Devices

A summary output is also available that adds total satellite program cost to the cost of launch vehicles for each satellite initiative. Each program is added to others in the group, and subtotals and totals for the mission model can be made available. Such listings for all satellite programs considered in the study are shown in the attached computer printout.

IV. LARGE SPACE STRUCTURES COST ESTIMATION

Many of the initiatives make use of extremely large but lightweight space structures that are applicable to various kinds of reflectors, antennas and solar arrays. These large arrays have been categorized into nine generic types as described in Appendix B.

For cost-estimating purposes, previous work done as part of a NASA study of large solar power stations (Reference 1) was drawn upon to quantify costs for large arrays. Figure 1 shows a cost-estimating relationship for basic mission equipment RDT&E plus unit cost versus weight of such equipment. Figure 1 also contains a plot of several OAO telescopes for comparison purposes. A projection of such costs for similar mission equipment, but of much heavier weight and larger sizes, is illustrated by the dashed line. Finally, plots are shown for active microwave and thin film mylar reflector cost estimates derived from the synchronous solar power station study described in Reference 1. It appears that the last two plots tend to bracket most of the types of large structures under consideration in this study. Accordingly, based on the information portrayed in Figure 1 and the technical discussion in Appendix B, a scale of factors was set up to quantify differences from the basic mission equipment cost projection. The factors selected for each type of large structure are listed in Table II.

It will be noted that the factors are the same for RDT&E and unit cost in each case except for Type 9. It is assumed that Type 9 would be difficult to develop but would be relatively inexpensive to produce.

Solar arrays are not included in the nine types described above; however, many satellite initiatives require large solar cell arrays. For cost-estimating purposes, it is assumed that array costs developed for the SSPS analysis described in Reference 1 could be applied in the current study. Accordingly, for large arrays the computer cost estimating relationships are modified to reflect a projected decrease in solar cell costs similar to those estimated for the SSPS study.

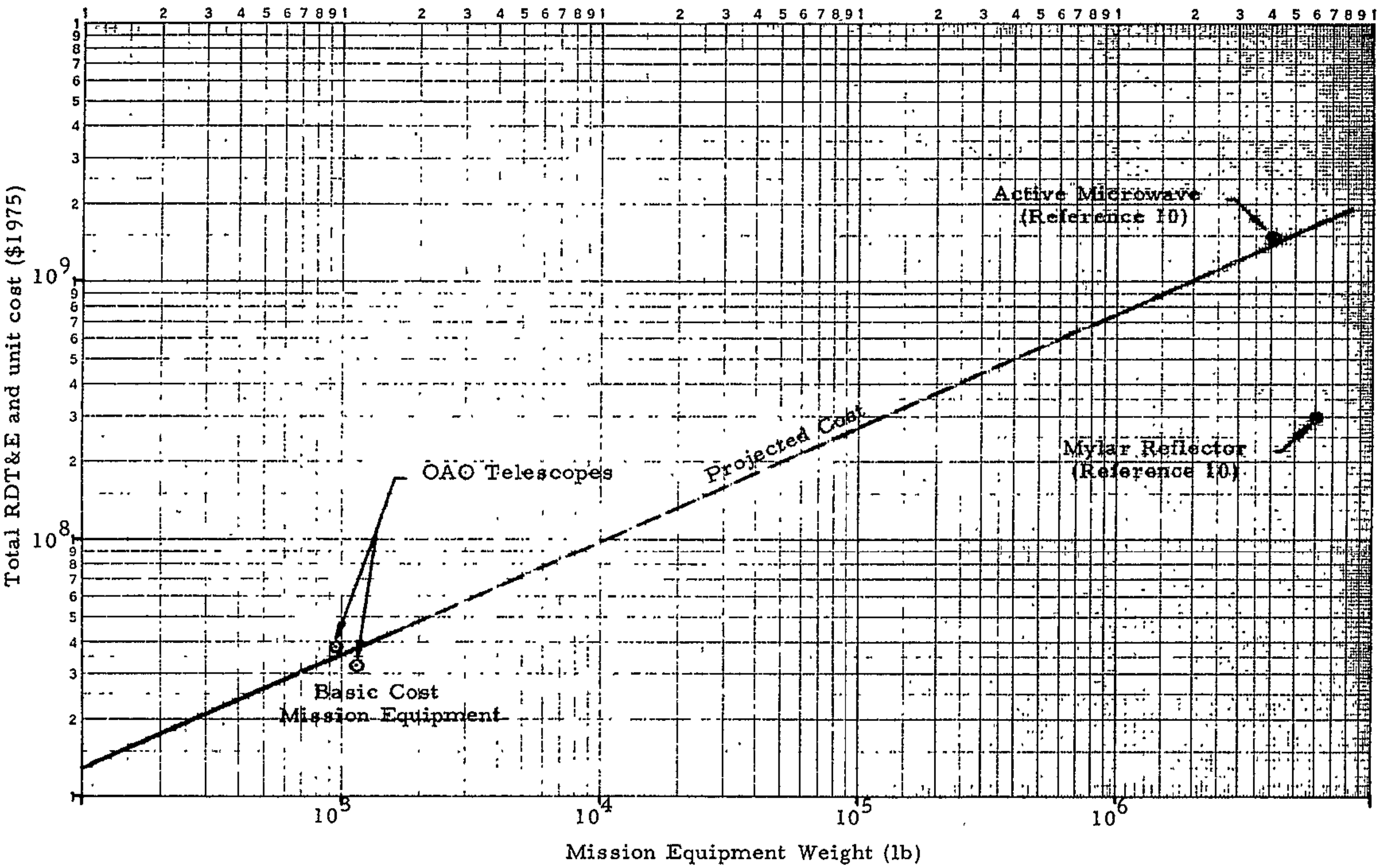

Figure 1. Mission Equipment Cost vs. Weight

Type	Description	Cost Factor	
		RDT&E	Unit
1	Optical Reflector-Thin Film Mirror	0.2	0.2
2	Optical Reflector-Double Thin Film Mirror	0.3	0.3
3	Optical Reflector-Cool Graphite Epoxy Mirror	0.4	0.4
4	Optical Reflector-Hot Graphite Epoxy Mirror	0.6	0.6
5	Passive Microwave Reflector	0.5	0.5
6	Passive Microwave Antenna	0.7	0.7
7	Active Microwave Antenna	1.0	1.0
8	Bootlace Lens Multibeam Antenna	1.5	1.5
9	Dielectric Lens Multibeam Antenna	2.0	0.2

Table II. Large Space Structures Cost Factors

V. LAUNCH VEHICLE COST ESTIMATION

The cost results aim to show total expenditures required for IOC and thus must include launch as well as satellite cost. A total of seven launch vehicles and upper stages were considered, and numerous configurations are possible by combining these building blocks. The launch operations cost assumed for each vehicle is shown in Table I of Appendix B.

RDT&E and investment costs are excluded from the figures shown in Appendix B. The costs represent preliminary estimates only and are not based on a detailed analysis of each vehicle.

VI. COST ESTIMATING ASSUMPTIONS

In summary, the assumptions pertinent to the cost estimates presented in this study are as follows:

(a) All cost figures are stated in terms of constant 1975 dollars.

(b) Dramatic cost reductions are assumed for large space arrays whether built as one large unit or as a large number of smaller but physically unconnected satellites.

(c) RDT&E costs are included for satellites only; not launch vehicles.

(d) Cost through IOC only is included; not continuing operations.

VII. REFERENCES

Business Risk and Value of Operation in Space (BRAVO), Analysis of Solar Cell Power Satellite System. Briefing to Dr. Peter Glaser, Arthur D. Little Inc. by Aerospace Corporation dated 18 Jan. 1974.

PROGRAM DIRECT COST SUMMARY THROUGH 1997
(MILLIONS OF 1975 DOLLARS)

	TEST SPACE TRANSPORTATION SYSTEM PAYLOAD TOTAL	LNCH VEH DIRECT	PROGRAM DIRECT
MILITARY OBSERVATION			
SURV MISS SURV	701.	150.	851.
EYEBALL VERIF	1867.	140.	2007.
SUB SURF-SONO	294.	39.	333.
PASIV BISTATIC	2016.	750.	2766.
DEEP SP BACKUP	621.	135.	756.
SAT INSP-TELE	293.	12.	305.
X-RAY INSP	329.	25.	355.
A/C IR SURV	500.	104.	604.
OTH A/C SURV	352.	12.	364.
BTLFLD SUR-PAS	246.	12.	258.
BTLFLD SUR-RAD	1587.	192.	1779.
BTLFLD SUR-LAS	938.	78.	1016.
SURV SPACETRK	346.	78.	424.
OCN SURV-RADAR	537.	48.	585.
OCN SURV-LWIR	1616.	48.	1664.
SYN DEF METSAT	232.	39.	271.
LAS SUB DET-LE	848.	60.	908.
LAS SUB DET-SE	771.	45.	816.
LAS SUB DET-SO	110.	39.	149.
LAS SUB DET-IS	417.	52.	469.
SUBTOTAL	14021.	2059.	16080.
MILITARY COMMUNICATIONS			
DSCS X	218.	25.	244.
SURVSATCOM II	379.	78.	457.
PROLIF COM PKG	208.	0.	208.
DEEP SP COMSAT	418.	117.	535.
ADV SURV DATA	349.	65.	414.
ATTACHE CASE	0.	0.	0.
SUB COMM-ELF	182.	12.	194.
SYN MANNED CCC	1706.	70.	1776.
TTC READOUT	159.	25.	185.
RPV CONT/READ	182.	13.	195.
GI PERSONL COM	288.	14.	302.
SUB LAS CRSLNK	142.	13.	155.
LASER COM-SUBM	140.	13.	153.
SUBTOTAL	4371.	447.	4818.
MILITARY WEAPONRY			
DEEP SP DETER	3011.	700.	3711.
LASER INTRCPTR	1137.	210.	1347.
ABM LAS JAMMNG	4984.	180.	5164.
TACT SP MW WPN	8796.	1800.	10596.
ABM LASER-CHEM	21460.	1440.	22900.
ABM LASER-MIRR	96971.	8000.	104971.
SUBTOTAL	136359.	12330.	148689.

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PROGRAM DIRECT COST SUMMARY THROUGH 1997
(MILLIONS OF 1975 DOLLARS)

	TEST SPACE PAYLOAD TOTAL	TRANSPORTATION LNCH VEH DIRECT	SYSTEM PROGRAM DIRECT
MILITARY SUPPORT			
A/C COCKPIT DIS	136.	13.	149.
HOM MIS DES-GR	102.	12.	114.
HOM MIS DES-SP	125.	12.	138.
BTL FLD ILUM-S	299.	27.	326.
BTL FLD ILUM-L	1257.	150.	1407.
RAD BELT DEPLN	361.	78.	439.
SML SENSOR DIS	274.	12.	286.
BOMBER BEAM PR	62527.	4800.	67427.
SUBTOTAL	68182.	5104.	73286.
CIVILIAN OBSERVATION			
ADV RES/POL OB	665.	48.	713.
FORST FIRE DET	206.	24.	230.
U.N. TRUCE OBS	178.	12.	190.
NUCL FUEL LOC	533.	26.	559.
BORDER SURV	154.	13.	167.
COASTAL RADAR	1067.	75.	1142.
ASTRO TELESCOP	669.	24.	693.
ATMS TMP SOUND	330.	12.	342.
SUBTOTAL	3802.	234.	4036.
CIVILIAN COMMUNICATIONS			
GLOB SRCH/RESC	572.	130.	702.
DISASTER CONTR	259.	13.	272.
URBN/POLICE RD	259.	13.	272.
ELEC MAIL TRNS	266.	13.	279.
TRNSPTN SERVCS	364.	260.	624.
POLL/VOTE COLL	259.	13.	272.
NATL INFO CNTR	364.	54.	418.
PERSONAL COMM	305.	14.	319.
DIPL/UN HOT LN	187.	39.	226.
SUBTOTAL	2835.	549.	3384.
CIVILIAN SUPPORT			
PWR GEN-NUCLR	10647.	5040.	15687.
PWR GEN-RTG	2637.	900.	3537.
PWR GEN-SOLAR	9294.	1620.	10914.
NUCL WASTE DIS	404.	28.	432.
A/C BEAM POWER	62627.	4800.	67427.
NITE ILUM-SOLR	939.	196.	1135.
VEH SPEED CONT	568.	42.	610.
SPACE DEBRIS	0.	130.	130.
OZONE PROTECTN	0.	1680.	1680.
LO COST NAVSAT	115.	13.	128.
SUBTOTAL	87231.	14449.	101680.

MILITARY AND CIVILIAN